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# **A Postmodern Reconstruction of Floodplain Management Methodology**

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**A thesis  
submitted in fulfilment  
of the requirements for the Degree  
of  
Doctor of Philosophy  
at  
Lincoln University**

**by  
Keith D. Morrison**

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**Lincoln University**

**1995**

## **A POSTMODERN RECONSTRUCTION OF FLOODPLAIN MANAGEMENT METHODOLOGY**

by Keith D. Morrison

A critical reconstruction of floodplain management methodology has been carried out in an attempt to explicitly incorporate ethics; including an appreciation of sustainability. This has been undertaken by adapting a social constructionist and pluralist approach to appreciate the multi-disciplinary context of Aotearoa/New Zealand where diverse knowledge systems occur, and to theoretically ground public participation in resource management.

Social constructionism has been construed to be a process of modelling, in accordance with systems theory. Integrative modelling including: hydrological, risk, economic, sociological and ecological analyses has been attempted. It has been carried out within the tradition of Soft Systems Methodology. It has been found that crucial to the success of integrating ethics into this process has been the overcoming of privilege being given to any discourses from particular disciplines, professions, cultures or publics. It is argued that this has been achieved, without resort to relativism, by incorporating analysis of the quality of information by realistic analysis of imprecision and uncertainty through the use of possibility theory and fuzzy logic, as well as probabilistic and deterministic calculi. It is further argued that a pragmatic epistemology based on a nesting of metaphors, with the use of an organismic metaphor defining functionality as central, is able to structure a hierarchical decision-making methodology enabling Expert System algorithms to be developed which can aid in the decision-making process.

It is concluded that such hierarchically structured Expert Systems can encourage social construction of situations which can help integrate actors' views and enable flexible floodplain management to co-evolve with the floodplain. Theoretically this should produce better conditions than existing at present, for sustainable occupation of floodplains, while also increasing the meaningfulness of professional engineering practice.

**Keywords:** floodplain, resource, engineering, management, multi-disciplinary, multi-cultural, postmodern, social, construction, reflexivity, expert, systems, methodology, ethics, metaphor, hydrology, risk, economics, public, participation.

# Preface

*This research is dedicated to the Clutha River.*

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The nature of this research is different to that which is perhaps normal in engineering research. There are two reasons for this. Firstly, because the art dimension of engineering has been taken seriously and attempted to be integrated with the scientific aspect. Secondly, a new culture is emerging in Western societies which is reflexively self-critical and refusing to privilege scientific discourse in the way that it has in the past. This is of immense practical concern for countries which are the consequence of recent European colonization (e.g. Aotearoa/New Zealand) and have indigenous cultures present which have very different knowledge systems. Because of this an attempt has been made here to look at first principles, which are philosophical, in relation to engineering and resource management methodology. In an attempt to transcend specific cultural metaphysical justifications, a pragmatic epistemology has been adopted. In doing so relativism has been avoided through concern for the purpose and success of types of knowledge and analyses. The hope is that a holistic synthesis has been achieved which may have special relevance to the bicultural situation of Aotearoa/New Zealand.



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# Notation

$/A/$	truth value or certainty of A
$\Pi$	possibility measure
$P$	probability measure
$N$	necessity measure
$Cr$	credibility measure
$Pl$	plausibility measure
$CP(A;B)$	compatibility of A with respect to B
$\neg A$	not A
$\wedge$	conjunction
$\vee$	disjunction
$\rightarrow$	implies
$\leftrightarrow$	equivalence
$\min$	minimum
$\max$	maximum
$\sup$	supremum
$\inf$	infimum
$\mu_A$	membership function of A.
$\pi$	possibility distribution
$\alpha$	a specified membership value cut of a fuzzy set or possibility function.
$\tau$	fuzzy truth weighting
$p \circ f$	composition of p with f
$x$	precipitation value
$y$	streamflow stage
$\omega$	scale parameter in extreme value functions.
$k$	shape parameter in extreme value functions.
$u$	location parameter in extreme value functions.
$\rho$	exponential function parameter for Poisson process events'(rainfall) magnitude.
$\lambda$	exponential function parameter for Poisson process (rainfall).
$\beta$	exponential function parameter for Poisson process events'(floods) magnitude.
$\theta$	exponential function parameter for Poisson process (floods).
$y_T$	Gumbel variable
$T_r$	return period
$Q$	streamflow volume

$q_{100}$	dimensionless '100 year' flood
$Q_{100}$	'100 year' flood
$\ell$	duration of a flood
$f_e(y)$	erosive force
$F_e(y, \ell)$	erosion potential of a flood event.
$\xi$	total erosion potential in a period.
$T_d$	design period
$f_d(y)$	damage function
$F_d(y)$	cumulative damage function
$f_c(y)$	cost function
$C_d$	available capital
$T_c$	period for which capital is available.
$I$	total income
$D$	total damage

## List of Acronyms

GST	general systems theory
HAS	human activity system
HSA	hard system analysis
SSM	soft systems methodology
RD	root definition
CM	conceptual model
CST	critical systems theory
MVL	multi-valued logic
TFM	truth functional modification
ITFM	inverse truth functional modification
ES	expert system
MO	management option
RMA	Resource Management Act
NWSCA	National Water and Soil Conservation Authority
RCBA	CBA
GEV	MA
PMRM	
CBA	
GBA	
GIS	

## Introduction

*I do my utmost to attain emptiness;  
I hold firmly to stillness.  
The myriad creatures all rise together  
And I watch their return.  
The teaming creatures  
All return to their separate roots.  
Returning to one's roots is known as stillness.  
This is what is meant by returning to one's destiny.  
Returning to one's destiny is known as the constant.  
Knowledge of the constant is known as discernment.  
Woe to him who wilfully innovates  
While ignorant of the constant,  
But should one act from knowledge of the constant  
One's action will lead to impartiality,  
Impartiality to kingliness,  
Kingliness to heaven,  
Heaven to the way,  
The way to perpetuity,  
And to the end of one's days one will meet with no danger.*

Tao de Ching,  
Book one, Stanza 37 and 38.

This research was approached from an engineering background. Hence hydrological discourse was the means by which the topic of floodplain management was first considered. The major hydrological journals and practices were reviewed which exposed theoretical and practical development around a few central systems analyses. The research around was the development of increasingly sophisticated mathematical tools of analysis. There was one dissenting voice however, that of V. Klemes (1986) who argued that the systems analyses being developed and implemented along with the mathematical models had not been rigorously thought about. He questioned whether the approach and research projects arising were coherent and of any social worth. He lamented that all too often a PhD in hydrology comprised nothing more than the writing of computer programs. Klemes' criticism of the hydrological discipline and comments struck a note with me because of professional engineering work I was doing at the time developing software for floodplain management. I had developed questions that hydrological discourse did not



allow as legitimate questions, and even less could begin to answer. Therefore to be honest to research instinct there was no option but to consider the context of hydrological texts as Klemes implored. The context was found to be historical and multi-disciplinary. It was in Aotearoa/New Zealand in 1990 with Resource Management Law reform in full swing and with an Earth summit coming up to consider 'sustainability'. This widened context informed that hydrology was required to involve not only an understanding of certain systems analyses, but also system theory itself, along with logic and mathematical theory. Also, in recognising that the technical analyses had to be carried out in a social context to make them relevant, meant that ethics, economics, sociology, risk theory and decision theory were also implicated.

Ericksen's (1986) work on floodplain management and systems analysis was discovered quickly to be part of a tradition that was aware of the questions arising out of the context, however consideration of development within the particular disciplines led the research to be critical of Ericksen; both in consideration of philosophical assumptions made and in the comprehensiveness of the system modelled.

Brainstorming intuitively into a mystical multi-disciplinary 'cloud of unknowing' led eventually to the reconstruction of a methodology. The discovery along the way of Soft Systems Methodology (SSM), initially formulated by Checkland (1981), was the seed that germinated into the tree able to reconstruct the multi-disciplinary discourse. The multi-disciplinary study that resulted could not be carried out within any particular discipline's discourse. So to use a SSM term, a 'rich picture' had to be discovered and expressed before a system was able to be reconstructed that was appropriate. The rich picture is developed in all chapters and comprising fully Chapters 3-5. It has had to scope issues as diverse as spirituality which Maori value highly and so has to be taken seriously and rigorously appreciated; ecological and environmental ethics questions associated with sustainability; fuzzy logic as a needed extension of logic traditionally used in hydrology; economic analysis, and language itself because a multi-disciplinary 'discourse' was required.

The chapters are arranged so as to lead from creation of a 'rich picture' to a systemic analysis that SSM terms a 'conceptual model' (CM), however because they have been partitioned along disciplinary lines so as to explicitly reveal the multi-disciplinary nature of the research, the change from creating a rich picture to a conceptual model of a reconstructed system is fuzzy.

However within SSM, unresolved philosophical issues clouded the discourse as pointed out by Checkland (1981) in his wonderfully explorative book 'Systems thinking,

Systems Practice'. Therefore to fulfil Klemes' plea to attempt to base floodplain management on a coherent theory these issues had to be taken up. A journal Checkland has been editor of, 'Journal of Applied Systems Analysis', was the initial vehicle for consideration of these issues. This led to a realisation that postmodern philosophies were the best basis as he alluded to himself, though without using the term, when lauding the value but difficulty of the philosophy of A.N. Whitehead (1929). Hence the title of the thesis.

In keeping with postmodernism my approach is collage so as to avoid making essentializing assumptions. Juxtapositioning is used as a methodology to express relationships which cannot be imaged naturalistically with metaphor. This frees up language to be used explicitly as metaphor so as to be able to generalise and make exceptions without incoherence. In avoiding making assumptions this postmodern understanding has developed engineering methodology explicitly as an art form.

The script of the thesis is best appreciated in light of the view of one of the postmodern traditions, that of ecofeminism. It can be usefully considered in terms of the metaphor deriving from activities traditionally associated with women's work; weaving and agriculture, in contrast to metaphors found to underpin traditional engineering methodology and traditional men's occupations, warfare and management. However paradoxical this may be for a study of *management*, it is best to approach the text as a tapestry with different threads appearing and reappearing as you follow intertwining discourses to give an overall woven picture where insights have been nurtured to allow understanding to grow because deep roots have been implanted and there has been space to let the discourse extend unhindered.

# Methodology

A significant feature of this research is that the methodology implemented developed along with the research. This began as any research does when methodology is considered, but instead of becoming fixed thus giving rise to a set of methods, the methodology continued to evolve with the research being carried out. The questions being asked changed as well as the understanding of what was being done. At a point in the process this was reflexively recognized. It occurred when the postmodern moment of the research was appreciated. The postmodern realization led to recognition that a fixed methodology implies a fixed metaphysic, and when multiple metaphysics had to be entertained and even juxtapositioned as metaphors and attitudes, no methodological standpoint became possible. An initial presupposition that some best or better rationality could be obtained through incorporation of multiple perspectives, indicated by the original title of the thesis 'A rational approach to floodplain management', was replaced with a more challenging requirement and rewarding realization; the need for wisdom.

The methodological evolution can be considered as two threads which intertwined and informed each other, along with the applied research into floodplain management. Firstly the philosophical search for a coherent basis on which to base methodology. Secondly, the development of a general methodology that could be multi-disciplinary and serve as the basis with which to carry out the specific development of a floodplain management methodology.

Therefore this chapter is in three parts:

- (a) An outline of the evolution of the philosophical basis which directed research into methodology.
- (b) An outline of the evolution of the general methodology which directed the research into floodplain methodology.
- (c) An outline of the sequence of methods that were used.

## 2.1 PHILOSOPHICAL EVOLUTION

Being enamoured by rationality this began by attempting to determine the formal logic required for analysis so that it could be applied across disciplines; to develop a trans-discipline rationality. This was recognised to be able to be fuzzy and also to form an

iterative process along the lines of Popper's (1958) evolutionary critical rationalism. Refutation was sought from information about theory, and then from the possible options new *rational* beliefs developed which enabled prediction to be made which more information could refute at anytime. What seemed to be required was to be creative, coherent and sophisticated enough to create a belief that was adequate in face of possible refutation.

Two lessons forced the rethinking of this approach. Firstly the conundrum from logic expressed by Godel (see Hofstadter 1979 and Stewart 1975) that mathematics as a rationality cannot have its premises internally justified. Or in other words it is reflexively incoherent. Some meta-justification is required which is infinitely regressive. Even though this does not stop beliefs being formed within critical rationalism it does stop belief in rationalism basing its beliefs on mathematical logic. Further exploration of the justifications proffered for rationalism did nothing to suggest that other coherent bases could be found. The only possibly coherent suggestion found was the possibility that human ideas are linked to what is real because God has made human thought to be so - the argument Descartes used to justify the rationalism that formed the basis of the modern era (Sherburne 1966). This was not found however to be a commonly held theological view and so it was not accepted either. A second concern is that of methodological individualism which has also had a Cartesian modern foundation. Sociology was found to show however that the individualistic models of essential human nature are ideologically set within social practices of modern economic systems. Therefore the conclusion made in this research is that the individualistic creation of beliefs that critical rationalism professes is inadequate.

At first the phenomenological systems epistemology of Checkland seemed to achieve a non-rationalist (empiricist) epistemology, and one that respected different socially mediated worldviews because it allowed multiple perceptions of reality and hence disciplines' views. Further the critical/transcendental realism of Bhaskar's (1978) philosophy of science is consonant with it thus enabling a place for both reductionist and systems science. From this a multi-dimensional and hierarchical model was developed. The difficulty encountered with reflexive incoherence in Godel was resolved through adopting a realist view towards Wittgenstein's 'language games' considered to form social organisation (Woodiwiss 1990). Even ethical issues were able to be analyzed according to A.N. Whitehead's postmodern process philosophy but rationalism had to be incorporated. It was the postmodern concern for reflexive coherence that led to the metaphysical assumptions of this framework being questioned. A.N Whitehead's acceptance of a

Platonic and hence rationalist approach is almost unique in postmodernism. Another exception is Ferre (1990). It was found that most postmodernism took far more to heart what had originally been concluded; that rationalism has to be fully overcome and reflexivity fully embraced. This became a necessity when encountering Maori metaphysics which were very different. Following the lead of Heidegger, meditation to transcend rationalism so as to directly intuit wisely became the only possibility of achieving the sought-for coherence. This led to the recognition of unity beyond language being pointed to by religious traditions at the heart of cultures' worldviews (Maori and European heritage), and so it came to be decided that intuition and vision (the non-rational) has to be the basis for coherence.

All ontology and epistemology came to be seen to be socially constructed myth using metaphors that created worlds for people to live in - language games. Thus the tidy and comprehensive realist systems ontology could still be accepted as a helpful framework for methodology but could not be accepted as reality except in the sense of a socially constructed and contingent one of quite general use but not essentially true. Nevertheless it proved to be a resilient one and instead of replacing it, the metaphor was egalitarianized and made to fit the requirements of analytical psychology to be a good image to meditate upon. It was made circular like a mandala with no hierarchy. Further it was made into reflexive spheres which enabled a visual way to negate realism while also being able to be linked with religious imagery.

Thus, as with the systems myth that has been contingently held, other myths could be deconstructed through use of this same reflexive method. The concern became more one of attempting to find common threads between myths as *revelation* through intuition of the spiritual. The spiritual came to be seen as the only basis for coherence as it transcended all categories and hence cultures and metaphysics. Awareness of it through meditation came to be seen as the basis for wisdom, ethics and the reconstruction of worlds. A radical postmodernist and social constructionist philosophy came to be held.

## 2.2 METHODOLOGICAL EVOLUTION

As soon as it became clear that the philosophical basis was not straightforwardly Popperian, methodological concerns had to become reflexive. All that could be done was intuitive and creative development in the attempt to implement the changing philosophical basis. At first the need to creatively operate at different levels led to the recognition of why the Popperian methodological rejection of social science and analytical psychology was mistaken. Then the intuitive development of the multi-

disciplinary systems hierarchy was also rejected when the requirements to apply the systems philosophy proved to be reflexively incoherent, as mentioned above. Only when intuition became its own source of itself in spirituality did this become resolved - paradoxically in accepting the sacred or mysterious unknown.

The deconstructed systems philosophy has a correlate in methodology as SSM. Part way along the evolution, as the systems philosophy was being developed, it was recognised that the methodology for determining floodplain management methodology has characteristics of SSM. Therefore it was decided to rigorously implement SSM both in the methodology to determine floodplain management and as an integral part of floodplain management methodology. Accordingly, SSM came to be criticised as the systems ontology did also. SSM came to be reflexively considered and so reflexivity had to become an explicit part of determining the methodology to determine floodplain management as well as part of floodplain management methodology. There were two features to this final stage in the methodological evolution. Firstly, as inadequacy in SSM and component systems analyses became clear, a reflexive concern required a set of meta-values and meta-ideals to be constructed which serve as norms with which to evaluate what is appropriate and what is not. Ethics had to be explicitly included. These came to be seen as general guiding norms needing to direct the reconstruction of society at present, including floodplain management. There was/is no belief that they are absolute ideals in a Platonic or Whiteheadian sense, but they are the guiding norms needed now, and to a large extent are what are directing the ecological/social issues at present. Reflexive consideration requires them to be seen as contingently appropriate and contextually relative, and therefore no absolute basis is able to be given. The norms came to be summarized as sustainability and biodiversity. That norms are contingent was able to be incorporated into the reflexive spheres myth. All that remained uncontingent was the non-rational ethical relation of care or love consonant with wisdom that underpins the social construction of contextualized norms. Secondly, reconstruction involved reclaiming words. As Lawson (1985) put it quoting Heidegger, 'Words need to be able to speak again'. This in a radical way transcends any particular discourse and rationality. It enables language to be used freely. The only task left was to get some social acceptance of the reconstructions so that the new better worlds that can be potentially constructed can come into existence.

Thus a coherent methodology was settled upon, but this was only because the research project (the PhD thesis) came to an end. Further research can be expected to require further methodological development as well.

## 2.3 EVOLUTION OF METHODS

The philosophical and methodological evolutions were punctuated by epistemological breaks. These sometimes came at the end of extensive study of literature and sometimes by particular events or series of events. The first epistemological break and major methodological development came after extensive reading of some of the various disciplines involved; philosophy of science, ethics, multi-valued logic, sociology and systems theory. The methodological development progressed through extensive interviews with regional councils about the issues they saw in floodplain management. This period saw the development of the systems ontology. At the same time study of Maori language was under way after hearing the directive that to be able to appreciate the Maori worldview you had to know the language. Eventually this, coupled with attendance at the conference in 1990, 'Whakahokia te Mauri: Seeking common ground', involving extensive and intensive conversation with Maori and the postmodern Deep Ecologist W. Fox, led to the second epistemological break rejecting all metaphysics as relative and myth. After this, extensive periods of meditation exploring reconstruction of possible worlds, continued learning of Maori language and the study of postmodern literature led to the confidence to reconstruct floodplain management methodology. This reconstruction involved further interviews with regional councils and the beginning of seeking feedback from public forums as to the viability of the reconstruction as it was developed. The seeking of feedback involved giving seminars, attending conferences and carrying out a contract to develop an environmental decision-making model for the Canterbury Regional Council.

# **Engineering ethics: From modern to postmodern**

Accepting that ethics is a branch of philosophy, and systems theorists' arguments, e.g. Churchman (1974), that philosophical inquiry is essentially never-ending reflection and broadening of the context of concern, it should not come as a surprise to find that the concern for engineering ethics has required the review of many disciplines, and that many disciplines comment on the issue. A common thread is found throughout however. It is that there is a change occurring from a modern worldview, that has focused on value-free objective science for technical goals, to a postmodern one that is focused on wisdom so as to express practical moral concern in specific contexts (social and ecological). The change forms a continuum.

At one end of the continuum there is the view that ethical concern is adequately covered by 'codes of ethics' held by professional bodies. It is found however that this understanding has little to do with ethical reflection and certainly not to do with broadening the context of concern. It is found to involve implicit adherence to a set of values (ideology) that is an expression of the present economic and political agendas. At worst these are held for the privileges they afford the profession. Never-the-less there is a place for a 'code of ethics'. It must however encourage the taking of responsibility for the foreseeable consequences of what engineers do in a broad context. The ethical value of a code is no better than the thought which has gone into writing it.

A step along the continuum is criticism of reliance on procedural norms of conduct. There is the linking of ethics to the expression of technical excellence. This can and is criticised similarly as still only concerning itself with technical concerns that are socially constructed and not taken responsibility for. Further along the continuum it is held that ethical reflection needs to be included in the very process of doing engineering: in the model making, and in the involvement within the institutional structures of society, so that engineers take responsibility for the consequences of their actions and accordingly affect social change for the betterment of society. As for example Tickle (1991) has said, 'What we must do to save the planet' is the 'refashioning of our society.'

At the end of the continuum is the view that unless engineers have developed



themselves spiritually so as to know what is ethical there is no hope that what they do will be of benefit to others and 'affect social change for the betterment of society'.

Naudascher (1983; p3) states:

'Every scientist and engineer should ask himself (herself) : is it right that I spend all or even part of my time studying atoms and machines, when I know so little about myself and hardly anything about human nature and the web of society, and when I must doubt whether I shall put my studies to proper use?'

Starting with the issue of the appropriate use of codes, the different dimensions and aspects of the issue are reviewed and developed. Through the discussion the need for a postmodern approach emerges and it is developed in response to specific aspects that arise.

### **3.1. THE PLACE OF RULES IN ETHICS**

There is a need to analyze the actual value and role that 'codes of ethics' can potentially have, as well as the norms of conduct that they demand.

The first question that has to be considered is whether codes of ethics enable ethical understanding to be adequately incorporated. This translates as whether adherence to a set of rules is appropriate for enacting ethical obligations. There are two types of arguments for this position. One type is deontological arguments and the other consequentialism ones. Deontological arguments claim that there are rules which a person should obey out of duty. Kant has been the source of support for a modern formulation of this view (e.g Attfield 1987). His view was that people should never be treated as means, but only as ends, and that this demands by force of reason certain ethical requirements in interactions with other people. Ethical oughts are those that one would like to be universally applied, including towards oneself.

Consequentialism is concerned with the consequences of actions and denies that an action can be deemed ethical in itself. This position argues that the ethical value of an action is given by the consequences of it. This view is generally concerned with optimific behaviour that maximizes the utility for ends ascribed intrinsic values. Utilitarian ethics is an example where the decision-rule as to what is optimific is simply maximum total utility (see Chapter 9). The practice-consequentialism (and rule-utilitarian) version of it argues that often it is optimific to follow certain rules, because if everyone did then the consequences would be optimific. This view is distinct from the deontological one in that it always allows for special cases to override the following of rules if it can be shown that

in these specific cases it is not optimistic to obey the rules. The rules are closer to being principles. They should be obeyed unless there is a better reason not to do so (Attfield 1987). Although both approaches enable rules and hence codes to be formulated which procedurally integrates both deontological and utilitarian claims, a deeper analysis is required to give a more substantive conclusion as to how to use codes appropriately because the rationales for these two approaches contradict each other.

### **3.2 AXIOLOGY, LANGUAGE AND RATIONALITY**

Deontological ethics are criticised because it is not clear what gives rise to universal rules. The Kantian version begs the question as to how rational analysis comes to a universal rule. Presumably it cannot be done through a consideration of consequences. There are three answers suggested (Attfield 1987): direct revelation from an authority that knows (e.g. religious prerogatives based on the 'Word of God'), moral intuition and analysis of language. All three involve analysis and/or involvement which broadens the context beyond that which the rules making up a code are explicitly concerned with. Therefore the first two positions in the continuum of ethical positions are inadequate because non-technical matters have to be dealt with. Codes of ethics for professional groups necessarily involve deep and complex philosophical issues beyond technical concerns.

#### **3.2.1 The social construction of axiology.**

The attempt to gain a coherent view of axiology is a task postmodern theorists have attended to with rigour. Perhaps ironically the result of this iconoclastic deconstructive methodology has resulted in the (re)discovery of the importance of the *sacred* and *spirituality*. The consequence in context of this research is that Naudascher's view ceases to be out on a limb. Also a way to integrate the various types of values perceived and used is able to be achieved.

The process necessarily has to begin with deconstruction which demands internal coherence in knowledge claims. Associated with social constructionism which does not accept rationalist epistemology nor any ontic claims (in keeping with radical empiricism e.g. positivism), the consequence is in agreement with Nietzsche who first suggested in recent times that all knowledge is metaphor (see Pasley 1978, Danto 1965 and Lawson 1985). Coherent knowledge is reflexive knowledge whose base metaphor is consistent with what the knowledge is claiming. For example, the use of an organismic metaphor defining functions is coherent with knowledge attempting to have functional role or

utilitarian purpose. Radical constructivism in fact adopts this typically postmodern pragmatic view to knowledge and adopts an organismic metaphor as primal (von Glasersfeld 1991). This requirement also defines the legitimacy of different types of knowledge. For example the use of the causal metaphor of transformation (and its tighter version of symmetry e.g in Newton's first law) is only used to express control and power, and therefore can only ever coherently be a subset of an organismic metaphor defining functions which are goals that the transformations through the use of a causal metaphor are intended to achieve. Note that this seriously critiques the notion that scientific knowledge is value free (see Chapter 4). Scientific knowledge is inherently ideological and an expression of a particular social nexus of goals, and is why ethics only concerned with technical concerns is merely supporting a set of pre-determined social relations, as mentioned above.

Language is not just limited to these two base metaphors however. Poetry and literature give expression to a multitude and potentially infinite number, including the mixing and juxtapositioning of them. Hence the use of the organismic metaphor is a subset of wider literature (context) which gives expression to activities other than the utilitarian one of goal achievement. Even though it may be able to be argued that engineering is 'essentially' utilitarian any consideration of ethics associated cannot be. Ethics is concerned necessarily with the context in which goals are defined; the environment in which the engineer finds themselves in. Therefore the question of ethics has to be concerned with the emergence of literature and language in general.

Maranhao (1991) has explored the process of getting to the basis of language. He points to the meditations of 5th century Augustine who outlined the meditative process as the discovery of the sacred (The Trinity) in the abyss beyond language, and that both the self and the world are constructed within language. He also discusses the contemporary philosopher Levinas who has carried on from the work of postmodern philosopher Heidegger, that all self exists only with others and that language creates them both. Thus knowing the world is knowing oneself and vice versa. It was termed the ontological relation by Heidegger (Lawson 1985, Wilden 1980). Appreciating the ontological relation overcomes the subject-object dualism that has been a fundamental and problematic feature of modern thought (Whitehead 1929, Sherburne 1966). In the attempt to refute any ontic world or metaphysic (or essential self or essential human nature), a relationship/expression more fundamental than knowledge is required. For Heidegger it was relating or care. Lawson (1985) has quoted Derrida and pointed out that there is the possibility of language without knowledge. Levinas developed it further from the perspective of the creation of

worlds (selves) (see Finn 1992). The most basic distinction that can be made is that of self/other, where in agreement with Wilden (1980) and Gaines and Shaw (1987), it is argued that this is the only possible legitimation that any system can have for it to be reflexively coherent. Levinas argues that fundamental to the distinction of self is that others emerging at the same time are like oneself, and transcend beyond oneself to the Sacred mystery just like oneself does. Therefore the most fundamental relation is that of absolute respect of the absolute in all others - to see *God* in all others according to Levinas. This essential relation beyond knowledge is what Augustine defined as the mystery of the Trinity of God. Finn (1992) calls it the *ethical relation*, and defines it to be what spirituality is concerned with. This is therefore arguably where ethics resides. It underpins all reality construction by language and so is non-natural. In fact it defines what is natural. It needs to be noted that this *gap* beyond knowledge and the natural is still real and is where wisdom is said to reside also. It is found when one knows that one does not know (Smithson 1991). Others point out that direct insight or intuition or vision beyond concepts is known in the ethical relation (Arraj 1988). Others point out how it is faith which occurs in the *gap* in contrast to beliefs which are metaphorical formalizations of the experience into language (Lane 1981).

Several consequences can be drawn from such an approach. Firstly, in keeping with the Christian approach alluding to an inherent dynamic of relations, growth occurs through respect of God in others, (Cupitt 1992). The spirit of *wisdom* and *truth* guides the use of language to help nurture the growth of others so they also engage as they grow in reflexive transcendence to also become wise and responsible nurturers through language - they construct their character through seeing God in others to gain the likeness of God themselves and thus to express *virtue*. Secondly, this is done socially as it is mediated through language. Therefore ethical activity is inherently cooperative and pro-active with visions which form the basis for ethical construction of collectively formed worlds for others to live in. Even more so, any world is either an expression of this or some perversion of it which can be corrected. Thus myth, cosmologies, poetry and literature, in the attempt to envision and encourage the ethical relation of respect and care for all nature, is at the basis of any ethical construction. This is the necessary context for engineering use of the organismic and causal metaphors.

An abstract version of such myths is one where separate others are defined and so are acknowledged as absolute ends in themselves, or in other words as having rights and intrinsic value. This abstraction is what allows and gives rise to both deontological and consequentialism ethical theories. Recognizing that they are an abstract formulation of an

open-ended context of literature and creativity points to the need to nurture moral intuition used to guide ethical systems such as these so that they can operate effectively. When doing so they can then provide a conceptual bridge between the wider context emerging from wisdom to the use of the organismic and causal metaphors that engineering uses.

The collective or otherwise nature of the construction of the various knowledge systems is significant. Both situations can occur for all three metaphor sets discussed. The mythical set is expressed individualistically as creativity in free artistic expression which through juxtapositioning of new metaphors can lead others into new insights of wisdom and care. It can also be collective when becoming religious and artistic traditions. The organismic metaphor is usually used collectively so that division of labour occurs in cooperation. However it does happen that people can create their own unique social nexus which leaves them an eccentric. The causal metaphor if used individualistically is what gives rise to magic and alchemy. If collective it is what is called modern science. It is worth noting that modern science arose out of the practice of alchemy. Modern science is distinct from magic in that it claims to have repeatability of effect through its experimental method which gives rise to its truth claims.

The process of being ethical can equally well however be considered in terms of the construction of the self or expression of virtues as an expression of spiritual growth, as it can of an ethical system pertaining to the world. The teacher of engineering ethics Weare (1991) takes this approach, in agreement with Naudascher, and points out the need for engineers to consider themselves as human beings which can act ethically. He considers what a 'human being-adequately-considered' is. Such conception of self enables one to perceive the intrinsic values in others and to allow oneself to grow through doing so. He outlines eight features:

1. The human person is a subject, distinct from the world's objects. They are expected to act consciously according to conscience, in freedom and in a responsible way, i.e. as a moral subject. No person is a mere means.
2. The human person is a subject in corporeality. Therefore it is necessary to respect the bodily integrity of people.
3. The human person is a being-in-the-world. Hence there is the responsibility to make the environment a better place for all to live.
4. Human persons are orientated toward each other, i.e. they are social.
5. Human beings are social beings and live in community, i.e. there is a public dimension to human life.

6. Human beings are created in the image of God to love and praise God. All persons in their self-actualization move toward a common sanctification, and by that manifest praise to God.
7. Human beings are historical. It is the task for each to continuously actualise and utilise their potentialities to reach a level of integration or wisdom.
8. All human beings are fundamentally equal. Each human is an originality, a unique individual subject.

This analysis by Weare is compatible with by an analysis by Schumacher (1973) that Naudascher (1983; p3) has quoted:

1. Each of us, as an individual, must get to know himself (herself) and to develop himself (herself) so that he (she) becomes capable of acting autonomously and responsibly.
2. Each of us, as a social being, must learn to live in harmony with his (her) neighbours and with Nature.
3. Each of us, as a spiritual being, must learn to act in accordance with his (her) moral impulses and to recognize goals which reach beyond him (her).

Such a concern for the existential dimension of virtues as an expression of ethics is becoming popular (e.g. Patterson 1992).

Recognising the ontological relation shows starkly the inadequacy of the modern view of the self and the world. The Cartesian definition of the self as a separate autonomous mind with rationalist powers led to both 'economic man (sic)' models of essential human nature and disenchanted materialism. It is against this particular very inadequate (perverse) social construction that postmodernism has deconstructed Western literature. It raises a couple of issues: what social group is constructing modernity, and how is ethics as a knowledge being distorted. Firstly, sadly, it is found that the engineering profession is party to the perversion. The reason is partly because it has accepted the economic model of human nature and resulting social institutions premised upon these. Along with this the acceptance of the value free view of science and the exclusive use of the causal metaphor has severed relations of responsibility for what is done through technology using science. Hence the consequence is that engineering is applied to suit the economic institutions of modernity. The views on engineering ethics on the first two steps of the continuum express this clearly.

Both mistaken views are examples of *essentialization* or *naturalism* where reality is confused with an image or concept or social construction of nature. It is termed the naturalistic fallacy, which distorts ethics by giving rise to the Is-Ought fallacy where descriptive statements are confused with normative ones. Even though all ethics as knowledge are naturalistic because they are expressed in language through metaphors, not all nature thus constructed is ethical - some metaphors may be perverse! Both early modernist utopias and notions of progress, and later examples of fatalism are examples. Engineering ethics in the move along the continuum has been the attempt to deconstruct modernism's Is-Ought fallacies which ideologically reproduce certain social practices and institutions.

Elms (1991) argues that there are three stages in ethical development of a person when they do grow: from adherence to rules, to adherence to principles, to the development of certain attitudes. As an example of the third stage is Fox (1990) arguing that Deep Ecology is concerned with developing a proper relationship with others - people and the rest of nature - and that this does away with the need for ethical rationalization. Fox's claim is however naive. As mentioned above it can and needs serve as a necessary conceptual bridge to guide engineering analysis through defining intrinsic values. Naess et al. (1984) in earlier expressions of Deep Ecology maintain this sense and argue for the need for ever *deeper* analysis of what the context is and uniqueness of any situation is. This definition of deep, as deeper questioning, is where the term 'Deep Ecology' came from. Engineering language hence needs to ask deeper questions so as to socially construct/nurture the growth of engineers, through the three stages that Elms points out, by concern for the context and uniqueness, or sacredness, of every situation. The formalisation of the integration of conceptual types required for such analysis is begun in Chapter 4 and completed in Chapter 9.

However the acceptance of the existence of intrinsic values is often questioned and needs to be clarified before such a formulation can be constructed. The response can be simply that accepting the existence of utility values logically implies intrinsic values (see Rolston 1982, Attfield 1987). Attfield argues that any concern for utility value or usefulness must ultimately refer to some intrinsic value, as usefulness is only in reference to something that it is useful for. The issue is simply one of who are the moral community with intrinsic values. Thus claims that intrinsic values do not exist can be interpreted as claims that the moral community does not extend beyond one particular social class or the human species or the individual making the statement.

Clarification of the relations between the types of values is also found to be

necessary. Hartman (1969) argues that there are three types of values, and that they form a distinct hierarchy. At the lowest level there is 'systemic' value. This refers to conformity. Hartman links ideology to systemic value. It is conformity in the sense of ideology as, '...a shared system of meaning and comprehension. It is a structure within which information is supplied and processed, directions are given and justification for certain behaviour is provided' (Bromley 1990). The second level is that of extrinsic value which includes utility value. This includes for example the usefulness of something to something else. The highest level is that of intrinsic value and is the something that has value in itself. Whereas systemic values are socially constructed, and extrinsic (e.g. utility) values are relative, intrinsic values are encountered as imperatives through intuition as discussed above. Another type of value and one which Hartman does not mention is exchange value (Wilden 1980). It is in between systemic value and extrinsic value. It is a form within a system that represents an extrinsic value. It is a sign, e.g. money. It does not refer to any particular extrinsic value (e.g. utility value for an intrinsic value) and so can be used to equate different extrinsic values.

### **3.3 THE RESPONSE TO ENGINEERING ETHICS BY PROFESSIONAL INSTITUTIONS**

Because professional engineers have a social role, ethical analysis pertaining to social issues is significant. Because professional engineers are also technologists general ethical consideration of technology is also significant. Review of these issues in light of the form of ethical discourse produces a deconstruction of the role of the engineer and technology. From that possible reconstructions are suggested.

The above review indicates that it is arguable that rules do have a place in ethical understanding. What is required to be considered is whether this has been achieved in existing 'codes of ethics' and how it can be done if not. Rogers (1985) reviewed the history of codes of ethics that have been held by engineers up until then. He analyzed them from the point of view of their concern for responsibility which he construed according to a consequentialist ethical theory to mean concern with the consequences of activities or 'ethical end-use issues'. Bayertz (1987) takes a different approach and suggests that because responsibility ensues from having control over something, and as science and technology is essentially power to control (because they use knowledge based on a causal metaphor) with technology increasing, so is responsibility. However neither this nor mention of concern consequences are expressed in engineering codes. Only general reference to welfare is made, in American codes, and community wellbeing in the



latest 1995 Aotearoa/New Zealand code. This has been taken to date only to mean refraining from negligence rather than explicitly looking at the purposes for the activities themselves. How the latest Aotearoa/New Zealand code will be taken is yet to become clear.

If there is to be concern for end-use issues however, Rogers argues, there are two issues that need to be faced:

1. Do individual engineers have obligations to criticise and evaluate the end-use(s) they are asked to serve?
2. Are engineers obligated to participate in actions aimed at end uses of which they conscientiously disapprove?

The first question refers to the issue of who the engineer serves. Traditionally the emphasis was on the client and it was a business relationship. In 1974, in the United States of America, it was included in most codes that the public interest was paramount. In 1995 the Aotearoa/New Zealand code has opted for a similar approach. However the revisions still do not face end-use issues because as Rogers (1985) put it, 'engineers are still seldom involved in setting, evaluating or criticising clients' goals or objectives, but may (only) reformulate them for precision or practicality.' There is no indication that the Aotearoa/New Zealand code is attempting to do anything different. To do something else would require to ask deeper questions about the nature of the context in which technology is put to use. However because an engineer is often merely an instrument or means to others' ends, questioning that which is using the instrument is seen as illegitimate, for economic reasons if nothing else. But if this is the case, engineers are not exercising their humanity and possibility of expressing virtue as growing, according to Weare (1991). They are neither expressing their ethical duty (deontological approach) nor ethical concern for consequences (consequentialism approach). The reasons for the stunting of the humanity of engineers and their inability to grow are developed in later sections, and found to be due to deep social structures involving technology - fundamental worldview assumptions.

Rogers continued his argument by reviewing alternative codes that have been suggested which do explicitly face the ethical end-use issues. Rogers has quoted a meta-code which suggests the alternative that engineers have responsibility to:

1. Recognise the right of each individual affected by a project to participate to an appropriate degree in the making of decisions concerning that project.
2. Do everything in their power to provide complete, accurate and understandable information to all potentially affected parties: and
3. To carry out to the best of their ability assignments which have been appropriately approved by the potentially affected parties, even if the engineers believe that they may (or even will) have consequences.

The emphasis is to include all 'stakeholders' and not just the client. The emphasis is on 'participatory democracy' rather than 'elite management'. There are however two specific difficulties that Rogers sees arising in the answering of the second question above. Both address the dilemma existing due to how the process of technological development is in an economic system based on institutionalized competition where survival is the main concern of firms, (Braum 1984), and therefore public dialogue with firms to decide goals and the means of development is essentially bad for the competitive advantage that new information gives. There is such a thing as the economics of information (e.g Arrow 1974). The two difficulties are: whistle blowing, and the suppression of new developments from a client who commissioned them.

Traditionally the answer to these two questions has been a 'counselling approach' (Rogers 1985) which insisted on antecedent prudence by engineers. It was the engineer's responsibility to foresee personal difficulties, and it was their fault if they didn't. It was a 'love it or leave it' (Rogers 1985) approach. In such a view there is no place for whistle blowing. 'Ethical end-use questions were not considered a professional problem. They are without professional precedent nor support' (Rogers 1985). Similarly, if someone who was commissioned to develop a technological idea suppressed it from their client it was considered subversive and a violation of the business 'faithful trustee' relationship. The result was that engineers had one option, which is supported by codes of ethics. It is was a 'know-nothing' approach involving avoiding thinking about end-use problems. It means neglecting or avoiding responsibilities. Engineers are in effect hired hands. Larson (1977) argues that this was a result of the failure of the professionalization of engineers to gain adequate autonomy. Rogers argues that it indicates ambiguities in the engineering profession which other professions do not have. He adds that 'autonomy is a sore point for engineers'.

If the alternative meta-code was held and used to base codes upon then the issues of whistle blowing and suppression would not arise, however it also implies the need for

social change because of its incompatibility with institutionalized competition. Rogers argues that it is this requirement which has made the substantive aim to improve social welfare as aimed for by the American 1974 code impossible to operationalize. There is a similar response to the recent Aotearoa/New Zealand code in the pages of the Institution of Professional Engineers of New Zealand's journal. Contradicting the institutional ethos of market competition requires a change of socially held worldview and ideology.

A possible ethically based criticism of the meta-code is that there needs to be a further clause added to allow for conscientious objection to rules, when something of overriding importance asserts itself. Rules socially constructed according to the meta-code are not able to be taken as deontological imperatives but rather more as rules in a practice consequentialism (or rule utilitarian) approach. The code should be seen as comprising principles rather than rules. Rogers argues that he would consider that sometimes an engineer could conscientiously object to assignments that have been appropriately approved by 'participatory democracy' when bad consequences have been overlooked. Engineers still need to maintain their personal integrity no matter how thorough the public involvement has been. There is a place for unique expertise and wisdom.

Never-the-less the ethos of the alternative code stands as being ethical and there is a requirement that there be no intention to privilege the engineering profession and its members, in keeping with Weare's injunction number 8. One way this can be approached is to replace the concern for the 'client' for concern instead for all the 'stakeholders' involved. This is what the new Aotearoa/New Zealand code has attempted to do. Stakeholders are all the people and beings with an interest in the situation. Ethically they form the moral community that needs to be taken into account. Further it is not clear that in general engineers or their clients have greater expertise than the other publics about what the community as a whole wants, and is good for it. It could well be the other way around (Perrow 1984, Rogers 1985). Only through open communication can it become clear who has wisdom. Also, the more people involved, the more wisdom and expertise is potentially present. It cannot be assumed that the engineer has the most, or even less, the sum total of wisdom and expertise present. The challenge is more one of how to integrate different discourses together (see Chapter 9).

### **3.4 INSTITUTIONAL INJUSTICE**

It has been claimed that there is an ethical obligation to try to change the social structures for the better, or at least not express injustice oneself, even if the codes of conduct demand it (Nielson 1978). This claim brings into stark relief the problem of

technology when it is recognised that a common counter-argument is the technocratic one that experts and professionals should be content to focus on their own area of expertise and to strive for technical excellence; the second step on the ethical continuum (e.g. Florman 1976, 1984). According to Kenny (1991) the assumption in this view, and that is used to justify it, is that there is an 'invisible hand' which is supposed to act in the same way it does with a 'free' market to somehow produce the ethical result. Kenny quotes the economist J.M. Keynes that it is 'one of the most extraordinary beliefs ever held by any society', and then calls it himself, 'one of the most egregious superstitions ever to hold the human mind in thrall' (see Chapter 8).

However there is more to it than this. There is another counter-argument coming from Luhmann (1990) that claims that the division of labour into functional groups that are self-legitimising or self-regulating, for example the engineering profession, are adaptive. Each self-regulating group is in constant adaptation to its environment, which includes the other groups in society and so overall society is more adaptive and able to avoid crises. Luhmann (1990) argues further that this form of social differentiation has been necessary for the achievement of instrumental values, i.e. utility values, sought in the modern world. In economic terms this means the production of the 'wealth' that western societies have achieved. The functional separation into focused disciplines of expertise has been necessary to achieve the high production needed for this wealth. The question remains, however, whether or not the achievement of wealth by such a market mechanism is ethical? Or in other terms, is wealth a value? It is a much debated issue (e.g. Dworkin 1980 and 1981). The axiological significance of wealth has to be considered to answer according to the ethical discussion given above.

Wealth is an example of an exchange value which in itself cannot differentiate between different utilities for different intrinsic value. Thus what forms the moral community is obscured through the use of wealth as a value. It is actually because of this obscuring of what are the appropriate goals, because intrinsic ends are obscured, that there can be the need for change in social structures. The social structures may be unjust no matter how much wealth may be being produced, and therefore the activities producing utility are not ethical. If this conclusion about the value of wealth is accepted then Luhmann's argument does not hold. The adaptiveness cannot be long term (see Chapter 4).

Further criticism of arguments along Luhmann's line is that the social differentiation manifested itself in the gradual separation of science into distinct disciplines and this means that there is no longer communication between each other nor with the rest

of society (Tribe 1972, Habermas 1971). In fact there is now a postmodern move toward accepting responsibility for consequences and hence the context of decisions which involves attempts at inter-disciplinary and multi-disciplinary activities so as to begin to develop greater understanding of them through communication between the disciplines of expertise. Also there is a move, through valuing participatory democracy, to develop communication and dialogue between the technical experts and other publics. The move is a response to address the 'costs' that have arisen with the gaining of wealth so as to pro-actively consider how to reconstruct social institutions/structures. The issue is found to be very fundamental (deep) because modern society is structured to privilege professional elites (Larson 1977). Toulmin (1982) and Tribe (1972) argue that this is partially explainable by the privileging of the ideal (social construction according to scientific method) of value-free objectivity by modern science. Evidence for this is the argument that the modern world view (including modern engineering) based on the use of science assumes a hedonist (self as the only intrinsic value) view of ethics because a subjectivist orientation or egocentricity is inherently socially constructed with objectivity (see Sherburne 1966 and Whitehead 1929). The reason is simply that objectivity means that the only intrinsic value which occurs is in the observer - all else is mere object(s) - and if scientific method is a privileged activity then so will scientists/engineers be a privileged social group. It can be a type of quite extreme domination and manipulation (Aronowitz 1988). Therefore there is the ironical situation of science claiming to be a 'value free' objective knowledge while being used to justify a specific ethical position which is seldom considered ethical (Wynne 1988 and Beder 1991).

### **3.4.1 Ideology.**

The concept of ideology is used to explore the relationship between fact (or knowledge) and values. Fundamentally the term ideology refers to a set of values that are linked to a set of ideas (Bromley 1990) however it has overtones that there is coercive manipulation occurring due to the many attempts to analyze problematic situations (e.g, Aronowitz 1988). One overtone is the reference to a mask, dishonesty covering up hidden agendas. The term is not however necessarily used in that way even where there is manipulation. It is used also in a neutral sense which sees manipulation carried out unconsciously as an unavoidable expression of cultural activity (Larrain 1979).

Hartman's (1969) axiology holds ideology to be an example of systemic value; the value type of least significance because of its unavoidable cultural dependence. Ideology only serves to maintain and reproduce a cultural form and power structures which are of

themselves of little value. What is of value is the utility of the technologies present in them, and what is of highest value is how the cultural rules encourage the enhancing of intrinsic values. Thus Attfield (1987) argues that it is possible to analyze cross-culturally transcending ideology. Never-the-less, even though ideology is of low significance, the consequences of ideology are immense. An axiological principle given by Hartman is that the higher the significance of value type, the more benign concern with them is. Concern with intrinsic value is achieved by those with highly developed sensibilities. Concern with utility value is seen as productive and constructive. However ideology has led to extremely destructive political and economic agendas through expression of unreflected upon emotions/passions. The reflexive process of becoming aware of one's assumptions leads to growing out of concern for the systemic value of ideology or style/fashion to be concerned instead at least with constructive activity producing utility and most importantly personal relating and aesthetics concerned with intrinsic values. Thus the postmodern concern is to expose, transform and transcend ideologies and after this to reconstruct ideology creatively so as to take responsibility for one's own viewpoint (ideology). It has to be guided by first understanding the intrinsic value ends being sought, and secondly by understanding the utility value of means to achieve them.

#### **3.4.1.1 Ideology and pluralism.**

If the unique intrinsic values of people and all beings is the feature of what determines appropriate utilitarian activities by the engineering profession then the codes of ethics should refrain from encapsulating specific systemic values, i.e. they should not be ideological and expect conformity to any style, fashion or culture; while simultaneously recognising that all expressions will necessarily be couched within them. They should encourage people to be responsible for their own world views and cultural membership. Smith (1991) argues that it is an expectation of professionals to respect the autonomy of those they serve. It should also extend toward the members of the profession. It does not require intolerance to demand tolerance. Nor does tolerance mandate others' intolerance. For example, there is debate in New Zealand at present about the Treaty of Waitangi and the aim of bi-cultural development in New Zealand between the indigenous Maori and the European settlers (e.g. Kelsey 1990). Smith (1991) argues that it is not acceptable to expect the ideology of bi-culturalism. Rather it should be accepted as an option people may freely accept. Unless people understand how to respect others in a bicultural way then it will not be achieved. The change has to be more than merely political in the sense of ideological allegiance.

The need to be non-coercive and pluralistic has special significance when it comes to the creation of cosmologies to encapsulate ethical visions. It is unlikely to be successful, and is unethical to try to create a new comprehensive cosmology or ideology for society or the engineering profession so as to be 'politically correct'. It is necessary rather that individuals and cultural groups be allowed and encouraged to take responsibility for development of cosmologies for themselves and to respect others'. Even though cosmologies and visions tell about intrinsic values there is freedom of metaphorical expression of how to do so. It is one of the ironies of cosmology and mythology that when it is mistaken for reality, in the sense of being accepted as a metaphysical objective truth, it produces the opposite effect from that it aims to achieve: it becomes perversely ideological rather than nurturing of intrinsic values.

#### **3.4.1.2 Ideology and 'Unruly technology'.**

Weare (1991), from his position of respecting the intrinsic value of a 'person-adequately-considered', calls engineering activity that is not concerned with consequences 'morally reprehensible' even though no code has yet explicitly demanded it. He also links the expectations of engineers to not be concerned with the consequences of their activities, to the demands of the military-business network that employs engineers. According to Luhmann's (1990) analysis of modern society, the activities of the military-business network and professional groups is necessary for the achievement of high wealth. It is only achieved by elite groups of experts, like engineers, concerned narrowly with their own area of expertise and with promoting it. The result has been labelled 'unruly technology' (Beder 1991, Wynne 1988). It is argued that the development of technology only has the appearance of orderly responsibility and that it is projected through the use of 'symbolic formal rationalizations' to maintain the trust of the public (Wynne 1988). It is argued that in fact, science and engineering is carried out in an ad hoc way for the agendas of the groups involved as Luhmann (1990) argues it is explicitly done so as to achieve high wealth. According to Luhmann's (1990) analysis this is a necessary ignorance. A corollary can be made from the argument of Kenny's (1991), that the maintenance of the superstition in the efficacy of an economic 'invisible hand' is also necessary, so as to satisfy the ethical concerns of the public. The agendas of the technical elites are seen as self-seeking, but because the overall benefit is greater wealth it is considered acceptable. Many reject it as unjust paternalism (e.g. Marcuse 1964, Habermas 1971, Nielson 1978, Tribe 1972, Blaug 1980). It is seen as a control of society by technical elites. The democratic process is not used for public participation but rather for the mandating of the

control by the technical elites who claim that they know what is best for the public (Fiorino 1989 and Chomsky 1992).

### **3.5 THE EMERGENCE OF MODERN TECHNOLOGY**

Habermas (1971) has analyzed the history of technology, and described the different ways science has been involved in it and how it is related to ideology. He uses the distinction between 'institutional frameworks of a society or the socio-cultural life-world' and the 'subsystems of purposive-rational action' that are embedded in it. He uses them to analyze the basic distinction made in sociology between traditional and modern societies (Mingers 1980 and Checkland 1981). The distinction has been termed the difference between 'community' and 'society' (see Chapter 4).

Traditional society refers to a society where the structure is an institutional framework grounded in an 'unquestionable underpinning of legitimation constituted by mythical, religious or metaphysical interpretations of reality - cosmic as well as social - as a whole (For example the postmodern approach developed here). Development of subsystems of purposive-rational action are kept within the legitimizing efficacy of cultural traditions.' (Habermas 1971). Modern society occurred when the development by technology permanently extended the subsystems of purposive-rational action so as to lose sight of their context and environment. The coherent nesting of the use of the causal metaphor inside organismic ones and mythical ones was lost. The process of modernization is seen as a pressure for 'rationalization' seen purely in terms of technical means. Neither the social goals nor ethical context is recognised. Depth was lost. The pressure for 'rationalization' involves an irrationality as the basis for its legitimation because there is a lack of concern for the consequences. The rationality is, as Wynne (1988) has argued, merely 'symbolic formal rationalisation' and hence an ideology rather than defining intrinsic ends. There is not concern for whether goals are actually achieved or not, nor what they are. As well as being ironical it is paradoxical. The extension of technical sub-systems with purposive-rational action, i.e the pressure for rationalization, requires the carrying out of the productive activity by the technical sub-systems in a way such that they ignore their goals, purposes and consequences. Concern for goals, purposes and consequences is replaced by a belief in automatic progress. Technology is seen as autonomous. Ideology changed from being a guiding vision about 'the central questions of men's (women's) collective existence and of individual life history,' as it was in traditional society, and is now being attempted to be reconstructed by some postmodernists, for example by this research.



When modern society emerged, science and engineering lost its guidance by a set of norms that was concerned with consequences and responsibility. This occurred because of the need to conform to survive, with privilege, in the competitive market institution of society. Larson (1977) relates this to the professionalization of engineering.

Professionalization was required so as to gain a secure market niche - something not required before the advent of modern society. Ironically again, the use of a body of 'truth' was required that had to appear purposive-rational to fit in with the ideology of the pressure for rationalization, but which was actually irrational and has a 'know nothing' attitude to goals and consequences. Rogers (1985) describes the social role engineers gained for themselves as comprising two claims:

1. All technology was the work of engineers.
2. All technology was applied science. Therefore engineers laid claim to a sophisticated body of knowledge, exclusively known by them.

These two claims allowed a degree of professional autonomy to be gained. Unfortunately however, 'the social role gave immense power to engineers who have no training' for it, as they are not trained to be concerned with the consequences of what they do (i.e. they lack managerial skills) and they are 'often willing to shift the responsibility onto others.'

(Rogers 1985). Ironically yet again, with the exaggerated claim to be the source of all the benefits accruing from technology, and the power that went with it that they couldn't manage, engineers are now the victim of being made to take the blame for all the problems due to technology. Beder (1991) claims that the rise in litigation against engineers is an expression of the loss of trust in engineers. This is a serious enough problem that the Institution of Engineers in Australia, in 1990, distributed a document to all of its members outlining the risks engineers face from litigation (Miller 1990). One of the main reasons for sending out the document was to stimulate discussion to seek ways to transform the professional role so as to face the ethical questions which were giving rise to the litigations. The authors were surprised at how ready the majority of the engineers were to reflect on these philosophical issues (Beder 1991). Mitcham (1987) argues that litigiousness is a consequence of the development of technology which gives power and hence responsibility, and the responsibility is maintained. Mitcham (1987) emphasises that it is the military background of engineering that is the cause of the lack of concern for consequences. He argues that this is why engineers continued to function as a profession with limited autonomy and an irrational 'truth' that is marketed. Military personnel are

not asked to be autonomous and responsible for the end-uses or consequences of what they do. They are expected to obey the hierarchy for the presumed public good. The irrationality according to Hottois (1987) reached its peak in cybernetics (see Chapter 4) where all is described in terms of information control feedbacks, and desired results are achieved in the same manner. Some practitioners of this methodology (see Bloomfield 1982) have had the aim to fine tune the development of the world's population in a global market. Once again the link to the military has been made (Hoos 1972).

The unethical irrational 'symbolic formal rationality' of engineering is then one where solutions are only seen as technical and not ethical and social. A situation Schrader-Frechette (1982) has called the 'fallacy of unfinished business'. Naudascher (1987) argues similarly to Schrader-Frechette that it only looks at symptoms and not at the real causes. The descriptive cybernetic technique is used to irrationally justify itself ethically because of its help in technological development of 'progress'. Further, these descriptions, like most analyses, are only ever idealizations (see Chapter 5) but unlike other situations where idealization is recognized, here idealizations are a requirement to mask the lack of concern for consequences. The uncertainty in the actual descriptions that could truly represent the unknown and unreflected upon consequences (see Chapter 5) is instead masked so the belief in 'progress' through technological development remains unquestioned. Unacknowledged idealization is a requirement of ideology to fulfil its coercive function (Thompson 1986).

An example is the World Bank's funded flood control project in Bangladesh. The French engineering team that won the contract showed disregard for the likely socio-cultural effects of the 250 km of floodbanks, that they proposed to make. It would destroy the only steady supply of protein for the local subsistence farmers - fish that get caught in pools after floods. 'The Bangladesh government of General H.M. Ershad was reportedly "infuriated" by the defeatist tone of the U.S. report and... "naturally preferred the bold French approach."' (Boyce 1990).

### **3.6 TECHNOLOGY AND PROGRESS**

Rogers analyses why the discussion of end-uses for technology as it has emerged is only rudimentary. He does so in terms of the ideologies or world views of the engineering profession. He uses the view of Florman (1976,1984) as a focus, because Florman, he argues, encapsulates the view of modern engineering. It is the second position on the continuum outlined above.

Florman's view is that engineering ethics is not held in a code. A code of ethics

according to Florman could only be superfluous to laws and regulations, or contradict them and so be invalid. For example, Florman (1984) argues that guild rules telling people how they should deal with each other are in violation of anti-trust laws. Florman holds as paradigmatic that the operation of the market is the means to achieve ethical results. This is the belief in the 'invisible hand' that classical and neo-classical economic theory holds to (see Chapter 8). Florman admits that market failure can occur, as it does on floodplains where uncertainty is high (Akerlof 1970), with the resulting unjust distribution of benefits and costs. He argues in accordance with neo-classical economic theory that there is therefore a role for regulation to help correct and maintain the market. Florman argues that the engineering profession is concerned with 'progress' and that the engineer's role is a positive social force in achieving this. Because of his belief in the 'invisible hand' he doesn't have to explicitly concern himself with consequences or the ethical end-use issues. His ideology is that the market will automatically produce 'progress'. Therefore engineers automatically serve ethical ends when they confine their focus on the task of being excellent in technical production, i.e. as hired hands.

There are however serious criticisms of the ideology of 'progress'. One is that it is an ideology in the sense of a mask to cover up corporate capital agendas, and so those who believe it are simply naive victims of coercion through conditioning. 'The present market institution amounts to de-facto social, ethical and political decisions made for the community by elements of the corporate, government or technological community' (Rogers 1985). Mitcham (1987) reviews historically an ill-fated attempt by engineers in America at the beginning of the twentieth century to be socially responsible. 'This ideology (the one holding the aim of responsibility) had not been severed from the self-interest and limitations of Capitalist institutions. Early codes of engineering ethics stress the primacy of obligations to employers, and until quite recently engineering ethics was commonly discussed exclusively in relation to the business context. The ideology takes on a politico-religious aura when turned against corporate capitalism.'

A second criticism against the ideology of progress is that the actual eschatology of 'progress' believed in does not exist. Hottois (1987) argues that in fact modern technology (technoscience to use his term) destroys all eschatology. He defines eschatology as a 'natural-cultural horizon' where humanity has a future. Or in other words, where sustainability is possible. For him modern technology is rather radically nihilistic and hence anti-sustainability. Hottois argues that eschatology is destroyed because technoscience is anthropocentric. As Hoitois (1987) put it:

‘That humans are the source of all value and purposes makes obvious its inanity and ideological function. Putting itself in place of natural-cultural horizon which had given it purpose and meaning, technoscience becoming the opposite of a meaning horizon, proves to be absolute meaninglessness.’

In other words, the context of technology is not considered. There is no depth. Hottois argues that ethical renewal is required by being aware of the philosophical significance of technological ideology.

Jalbert (1987) extends Hottois’ argument. Jalbert mentions how many are overawed at the apparent autonomy of technology. This view is implicit in the belief in the invisible hand. Like Rogers, Jalbert argues that the apparent autonomy is actually the defacto control by corporate capitalism through the market institution. The consequence of this mistaken view of the autonomy or inevitable ‘progress’ of technology is that, ‘there is the tendency to transfer value and dignity it possesses in its own internal states, to the meaning and value it has for life in general- hence the subsequent devaluing of and “dispensing of spirituality as the central point of life”’(Jalbert 1987) i.e. there is a loss of awareness of intrinsic value. ‘There is the subordination of spiritual and creative life to the needs of objective culture (i.e. institutions). Symptomatic of this confusion is the equation of technological progress with cultural progress.’ ‘Technological means undergo a metamorphosis into an end.....what was once conceived as a means undergoes an insidious process of transformation until it takes the place of life itself.’ (Jalbert 1987). Jalbert argues as already concluded that the solution is to separate out means and ends which means to recognise that utility value, which technology is concerned with, has meaning only in terms of the intrinsic values known in ‘spiritual and creative life’. This means that consequences have to be made explicit and means developed according to a causal metaphor nested in organismic metaphors defining ends, and mythic metaphors defining intrinsic value or sacredness. The ideology of ‘progress’ obscures the distinction between ends and means. To overcome this requires willingness to critique and to creatively change social structures.

In contrast to the attempt to critique through ethical renewal to creatively change social structures, Florman’s view has been called the ‘received wisdom approach’ (Rogers 1985). Florman argues that engineers should submit to the hierarchy of management and that engineering ethics is only concerned with technical excellence. Florman argues that ‘as a class, engineers have neither the power nor the right to plan social change...’ (Quoted by Rogers 1985). He argues that if engineers held the ideal that the public interest was

paramount, ‘...chaos would ensue. Ties of loyalty and discipline would dissolve and organizations would shatter.’ As mentioned above several commentators have however pointed out how Florman’s view reveals links between engineering and the military. Florman argues that law and regulation are adequate and that engineers have no place nor need to act outside of them nor desire to change them. Lockhart (1987) argues in contradiction that laws, regulations, legal precedents and other expressions of society regarding welfare should be items of evidence the individual takes into account in their own judgement about long term public interest. Other information available may reinforce or counteract the regulatory evidence. Regulation may lag behind. Lockhart takes a practice-consequentialism view of rules. The significant point about social action is that ironically, in contrast to Florman’s claim, it is especially engineers who have insights into possible consequences of technology and so have a special duty to be involved in social action to bring laws and regulations up to date! At present this is still however considered unprofessional (Smith 1991). Elms (1991) cites the recent case of an engineer (S. Beder) having proceedings brought against her because of her opposition to the pumping of untreated sewage into the sea at Sydney in Australia. Beder (1993) herself tells of other cases which starkly point out the absurdity and counter-productive nature of such proceedings.

### **3.6.1 Ethical progress in engineering.**

For engineers to express their expertise it is required that they do so in a way that ends are able to be appreciated. This requires recognition of chains of consequences beyond those concerned with the immediate goal and the intrinsic values that may be affected. In other words the moral community has to be extended. There does appear to be such an expansion in moral consciousness because there is a rise in environmental concern for sustainability and non-human interests. The introduction of Environmental Impact Assessments into institutional decision-making frameworks is an expression of this. Also there is the increasing valuing of participatory democracy in attempts to diminish the control (management) of society by technical elites (Fiorino 1989). It is becoming increasingly difficult for engineers to practise successfully with paternalistic attitudes claiming to know better than the public what is good for the public when the social context is the Public Sector, for example floodplain management. This is clear in the risk management literature (see Chapter 6). Hottois (1987) argues that there is a reaction to technoscience (re)discovering the connectedness of being, meaning and value. Hottois argues that, ‘the new consciousness "claims for itself values which are either forgotten or

frankly, ruled out by scientific-technical mentality: values of contact, communication, even communion; values of intuition and affectivity; values of creativity and particularity; values of simplicity, of spontaneity, of a true and authentic relationship with oneself, with others and with nature". "(P)ost-materialist aspirations of great multiplicity and diversity... lead to an improved style and quality of life" ? Hottois also sees the move as involving a voluntary renunciation of power so as to respect the environment and other cultures. The change is so widespread that many are claiming that we are entering a 'new world'. This is what has been labelled postmodern (e.g. Rappaport 1988, Toulmin 1982, Kenny 1991). The characteristic of this world view is a concern for responsibility through an appreciation of the context for activities (Caldwell 1987 and Hance et.al 1989). It is involving a new construction of roles, technical languages, analyses and methodologies (Kenny 1991). Many concerned with responsibility in engineering are using religious imagery and thought to do so (e.g. Coates 1991, Weare 1991, Naudascher 1983, 1986, 1987, Vanderburg 1987, Schumacher 1973, and Ellul 1980, 1981). It is from such thought that visions are being created to base reconstruction on to create necessary social change, including change in the engineering profession.

### **3.7 AN AOTEAROA/NEW ZEALAND RECONSTRUCTION**

A postmodern reconstruction in response to the deconstruction reviewed above can be carried out using the social constructionist axiology developed in Section 3.2. The role of individual reflexivity to be a creative participant in the social construction of language games is fundamental. Also the ethical basis is required to be non-naturalistic as any essence postulated as to what is good is contingent, even though it may well be the best expression available at the time. However to the extent that the ethical relation can be formalized in social activity as a language game through putting words (principles and rules) to it, then a vision that creatively improves society and the environment can be expressed.

Horowitz (1992) and Martin (1993) have considered how the non-naturalistic relationship can be symbolized so as to promote the attempt to be reflexive, to express virtue and improve relations. They have taken up the Buddhist concept of *interbeing*. Interbeing refers to how beings do not have an essential substance which makes them distinct. Whitehead (1929) has criticised the modern view of beings with distinct essences which he traces from Aristotle (see Chapters 4 and 5). Without defining beings as essential, relations become just as 'essential' as substances of unique beings. It just depends on how one wants to frame it, or in terms of radical constructivism, how it may

be useful to do so in any particular situation. Heidegger emphasized this by clarifying how all worlds are partial, and points out that humans are no-things: we do not have an essence or nature (Zimmerman 1992 and 1993). Zimmerman (1983, 1992 and 1993) points out however that Heidegger initially considered that only humans were no-thing in this way. All others were things who presenced because humans are absent. Heidegger defined metaphorically a non-naturalistic dynamic interaction between presencing and absencing. Later on however Heidegger saw other beings as also absencing. He saw four types: earth, sky, gods and mortals. Humans are mortals along with other creatures as we live and die. Our life is *unto-death* (see Macquarrie 1982). Gods are immortal as they do not die. They are ecologically called ecosystems and socially human communities. They may change (grow) but they do not die, and in terms of interbeing are not distinct from the mortals that live 'within' or participate with them. Whitehead developed a similar view emphasizing that 'gods' need not be assumed to be conscious beings. This view has direct parallels to both traditional indigenous cultures (e.g. Maori) and traditional Western culture.

Firstly consider traditional Western culture. As mentioned in Section 3.2 the Trinity of God (transcendent Father, incarnate Christ and the Holy Spirit) symbolizes the source of life. The *grace* of the *Holy Spirit* inspires the dynamics of life which are manifest as the fulfilment of growth as *Christ* (Maximos 1981). The gods of polytheism are considered by Orthodox Christianity to be an expression of the presence of the *grace* of the *Holy Spirit* and manifestation of *Christ* (Ignatius IV 1989). Note that such a view is in accordance with Whitehead's point that conscious beings do not have to be presumed to exist in interbeing. The growth of human beings is the life of Christ, as is the growth of all mortals, and is in the cosmic ethical harmony of God's love if they live to die giving themselves for others to live. Sacrifice/giving is the fundamental dynamic of growth. In terms of Heidegger's non-naturalism the cosmic harmony is the *cosmic dance* of the dynamic of presencing and absencing between beings; mortals and gods.

For traditional Maori culture there are also immortal gods who are equivalent to ecosystems and human communities. The god associated with human communities is language. Language is a being whom people participate with which makes community. Hence it has intrinsic value to be respected and treasured for its own sake. Ecosystems, for example the forest, have a god as do cultivated crops (Marsden 1989). Maori see gods as actively guiding the mortals who participate in their (the gods') life. The gods give authority to people to have leadership roles, and also give ethical direction (Matunga 1995). For example, humans are expected to respect rivers, who are gods. Personal

relationships exist between people and the gods. If people fail to listen and the relationship becomes broken, for example through a flood, then those who are flooded are punished by the rest of the community for breaking their relationship with the river (the concept of *murū* - see Patterson 1992). Christianized Maori views accord with Orthodox Christianity in considering that the family of immortals are symbols of the manifestation of God the Trinity (Tauroa and Tauroa 1986).

Zimmerman (1992) and Wright (1991) link the notion of *wilderness* to such a non-naturalistic approach. Being very careful to avoid naturalistic interpretations of the wild, they point out how it is awareness of natural 'grace' (Lane 1981) as 'wilderness' that is the basis for *civilisation*. A vision of wilderness is what civilises human beings to live the life of the gods, integrated into the cosmic harmony of God's love and to be ecologically adapted and hence sustainable.

These relations give rise to two types of structures and levels. The two structures are those of diachronic structures (in time) and synchronic (spatial pattern). The two levels are the individual and the collective. Synchronic relations are the structure of a god or community/ecosystem (collective) and are timeless and immortal but changing. Diachronic relations of individuals are the life of mortals which form the synchronic components of a god. The meaning for a mortal is given by the extent of integration into 'wilderness' or life of the gods and hence the life of 'grace' growing expressing the ethical relation.

From the point of view of what it means for an engineer trying to be ethical (civilized or in other words wild) it means being an artist in the sense of transcending form and hence essence so as to tap the source (ethical relation of 'natural grace' of 'wilderness') and in doing so constructing a new vision which a culture can better base its world upon (Klee 1966). Engineers need to have a vision/wisdom so that the world they help create is a 'grace'-filled one. A grace-filled one is one which is in the life of the immortal gods. This is appreciated by people principally aesthetically. The life of gods (e.g. wilderness) is known as beauty. It is true also for the expression of the language gods making up communities. They are the beauty of an articulate culture.

Such a 'grace'-filled world of 'wilderness' and 'civilisation' can be framed in terms of the meta-value of sustainability. This concept can use the abstraction of an artistically formed vision into the axiology of intrinsic and utility values. To be grace-filled is to respect all intrinsic values and so the meta-values of social justice (respect of all human beings) and bio-diversity (respect of all beings) arise as guides. To aim to fulfil these values requires integration into community or the life of the gods which means receiving



their direction. It is the god who is sustained! Humans live sustainable lives if they live in the life of the gods by adhering to their direction (feedback). Wilden (1980) develops a comprehensive systems theory using an organismic metaphor of how the gods give direction/feedback (see Chapter 4).

Individuals (mortals) are able to adhere to the direction given by the gods by transcending the language games through reflexive thought. All humans have a 'natural freedom' to do so (Schwartz 1986). The natural freedom has to however be used in response to the feedback from the gods which can be called 'moral freedom' (Schwartz 1986). It can be used otherwise. 'Negative freedom' is an expression of natural freedom in a way which instead of listening to wisdom coming from grace so as to integrate into the life of the gods, is reaction to actions within the language game (McGowan 1991). Negative freedom is an expression of competition, in contrast with integration (into the life of the community). Negative freedom has as its reference other mortals' disgraceful activities, rather than the immortal gods, and so the response is not life in grace, and is accordingly not sustainable. An extreme example is when a human dictates so as to create a language game which others are forced to play. It is the expression of control and domination and is termed 'positive freedom' (McGowan 1991) where natural freedom of others is not respected. If however positive freedom is expressed in a way which does respect the natural freedom of others then the result is 'moral freedom'. The respect of natural freedom of others is to respect the intrinsic value of others. To create language games respecting all is to listen to them all. The gods are listened to in others as well as in oneself in the spirit of wisdom. At that transcendent level self and others are not constructed. The duality of subject and object is transcended. Hence the ethics for engineering that Pirsig (1974) unsuccessfully but refreshingly sought, can be given a coherent basis. To not listen to others is accordingly to construct a self unable to listen to the spirit of wisdom and truth. The gods speak through natural freedom and creativity in response to 'grace' by all their member components. Moral freedom is *wild*, and hence *civilized*, and has no essence.

### 3.7.1 Conclusion

A non-naturalistic basis for ethics enables a coherent formulation of concepts in which to couch engineering methodology so that it can be ethical. It involves however fundamental changes in dominant worldviews and social roles. But the enormity of the problem demands such a paradigm shift in the attempt to regain some depth of understanding and wisdom.

# Systems

The methodologies most commonly implemented to carry out integration of multiple disciplines come from system theories based on the use of a functionalist metaphor. It is a metaphor used by many disciplines and allows parallel conceptualisation with Maori views, and so is particularly helpful.

The chapter consists of two parts. The first part reviews the philosophies of systems theorists and develops a coherent postmodern one for practical purposes. The applicability to integrated environmental management, including floodplain management, are the criteria used for the development. The second part reviews and develops how to operationalize the philosophy developed in the first part.

## 4.1 TYPES OF SYSTEMS

The term 'system' has been defined in many different ways. A very helpful and concise one is quoted by Ellul (1980; p76):

'An ensemble of parts or subsystems which interact in such a way that the components tend to change slowly enough to be provisionally treated as constants. These slowly changing parts can be called structures - if the exchanges occurring in their mutual relationships prove to be oriented towards maintaining or reproducing systems, they can be called functions.'

### 4.1.1 General Systems Theory (GST).

The mere consideration of how the term 'system' has been used, and/ or acceptance of one that seems to suit one's purpose, is however insufficient in determining the development of systems research. Ellul (1980) claims that 'The departure for all conceptions is obviously Ludwig von Bertalanffy's General Systems theory (see Bertalanffy 1969.) Checkland (1981, 1988b) also argues that the first systematic modern western development of systems research was by Bertalanffy.

Bertalanffy's work was based on the idea that the holistic operation of biological entities has a structure that is present in all facets of existence. Therefore the root

source of the term 'system' as it has been used in GST is in reference to how it is applied to biological study (i.e. the use of an organismic metaphor). This is not the only source of the multidisciplinary use of the term 'system' but it does refer to a significant tradition that the engineering profession is in direct contact with. Significant features of systems research can be seen historically in the development of this tradition.

The debates in systems research have centred around whether the meta-theory GST propounded referred to an ontological reality or whether it referred to an epistemological perspective. Koestler (1967 and 1969) developed a realist interpretation. Allen and Starr have (1982) argued however that this interpretation has slowed down the acceptance of systems research by the wider scientific community and prefer to use a utilitarian or pragmatic epistemological interpretation. Checkland (1991) has argued in a similar vein. Checkland outlines how an initial epistemological basis came subtly to be accepted as ontology in the initial stages of GST development. The mistake of Bertalanffy and Koestler, according to later systems research, was an over-enthusiastic use of induction when repeatable patterns at all levels of reality were noticed. It was mistakenly induced that organisation existed similar to biological organisation. Bertalanffy's view had a metaphysical claim which has become questioned.

Checkland (1988b) suggests that the term, 'holon', as coined by Koestler, would be preferable when referring to the claimed existence of real natural living systems. Checkland would prefer that the term 'system' be kept for when there is explicit use of metaphor. This is in keeping with Wilden's (1980) view that a *system* is a distinction without any ontological claim (see Chapter 3). Flood (1988) along with Checkland (1991) have begun a thorough analysis of the existence of ambiguities and fallacies present in systems research when the distinction between these two uses of the term 'system' is not made. Assuming the ontological view of Koestler leads to considering situations which are only metaphorically being thought about systemically, as if they ontically exist as systems in the same way that they do in biology. This can obscure the observance of trends and relations better interpreted by non-biologically based metaphors.

Never-the-less the notion of system has been applied in many fields, validating the view of Bertalanffy about the universal application of the GST meta-theory. But Jones (1978) and Checkland (1988b) point out that even here GST has limitations because its generality has meant that it is limited in its ability to help in any particular application. But GST remains of interest in its existence as a meta-theory, because it relates to the development of engineering methodologies on the general level of meta-theory. GST has been one of the main meta-theory underpinnings for floodplain management research

4.1.2 A systems typology.

Checkland (1981) has defined a systems typology.

1. Natural systems. These are ‘systems which could not be other than they are given a universe whose patterns and laws are not erratic.’ ‘(N)atural systems are the evolution-made irreducible wholes which an observer can observe and describe as such, being made up of other entities having mutual relationships. They are ‘irreducible’ in the sense that meaningful statements can be made about them as wholes, and this remains true even if we can describe their components and the relationships between the components with some precision.’

Checkland (1981) conceives of a hierarchy of natural systems. Figure 4.1

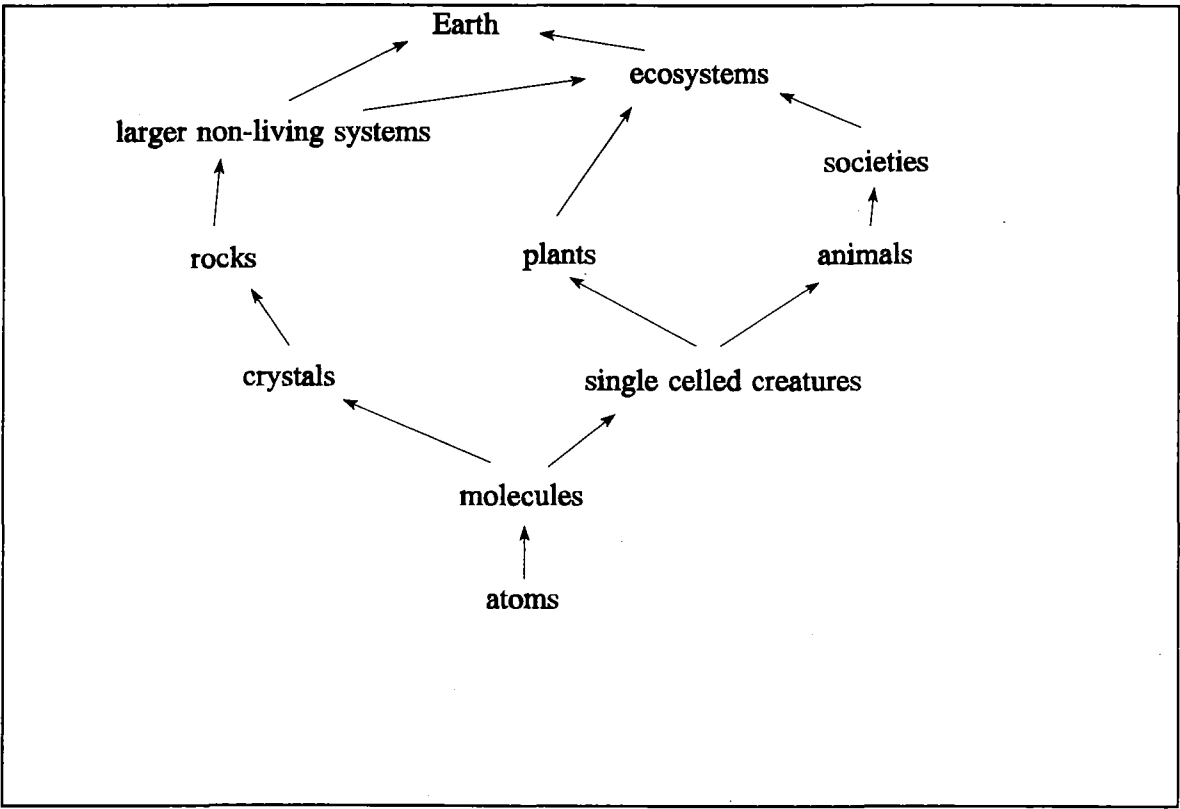


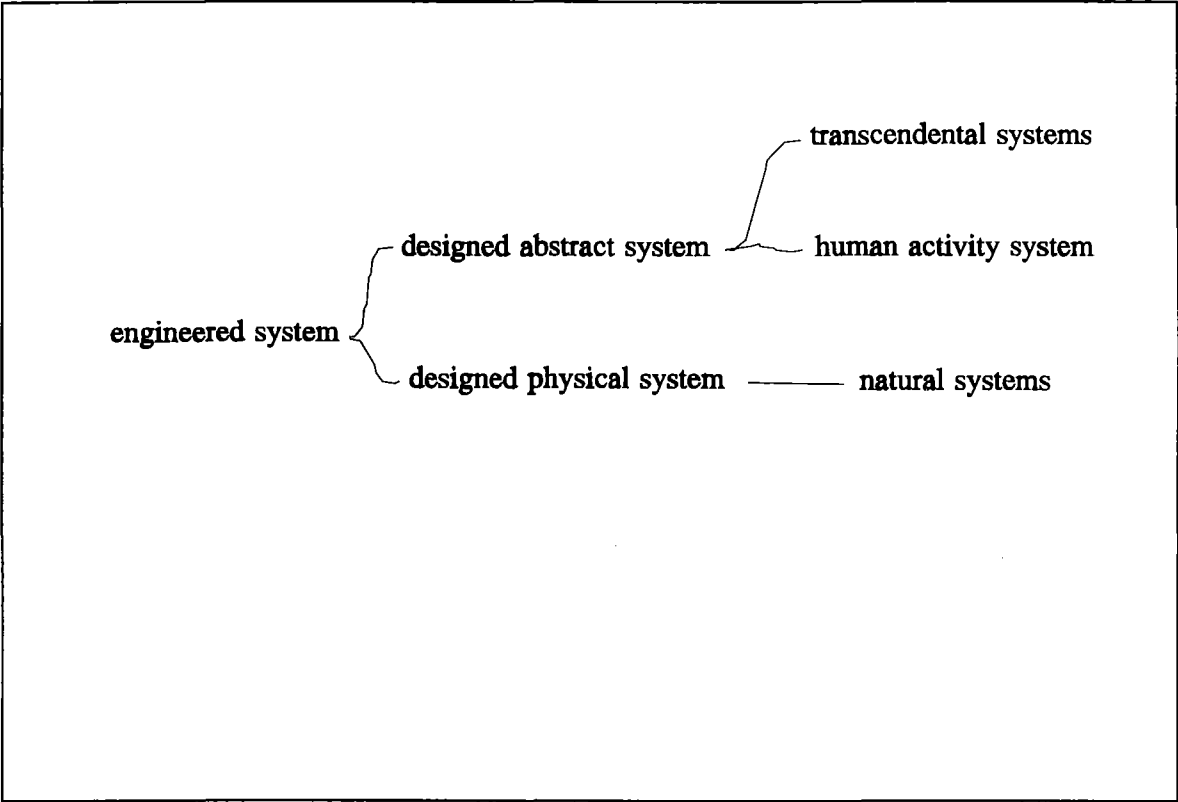
Figure 4.1; Hierarchy of natural systems.

schematically represents it.

2. Designed systems. There are two types: physical designed systems and abstract designed systems. Physical designed systems are physical constructions, and abstract designed systems are purely intellectual constructions.

- 3. Human-activity-systems. These are ‘sets of human activities more or less consciously ordered in wholes as a set of some underlying purpose or mission.’
- 4. Transcendental systems. Checkland defines these systems as ‘beyond knowledge’. They are attempted to be expressed by metaphysical systems and cosmologies.

This typology is helpful in allowing a definition of an engineering system and hence application of systems thought to engineering involvement in floodplain management



**Figure 4.2;** Systems typology.

(see Figure 4.2).

**4.1.2.1 Natural systems.**

As representative of natural systems, biological organisms can be considered because in GST they form the prototype. A biological system (what Checkland would prefer to call a *holon*), has been considered to be real (e.g. Weiss 1969). There are opposing views however. Allen and Starr (1982) for example do not accept any real existing systems (holons); not even biological ones. Starr and Allen’s approach and its variations form a significant tradition and has become the norm according to Jones (1982). Also in contrast to both of the above views, the non-systems, so called reductionist or

behaviourist approaches, accepts philosophical realism but considers that it only includes physical matter as described by Physics and Chemistry, with biological organisms considered to be really only chemical processes. Never-the-less, in spite of reductionism, the concept of function, and hence a whole (system) that defines the functions of the parts, has become accepted in both the fields of biology and social science (Outhwaite 1987). But the ontology involved remains unclear.

Weiss (1969) defined real existing biological systems (holons) mathematically in terms of the variance of movement of the physical elements in the system by Equation 4.1:

$$V < \sum_i v_i \quad (4.1)$$

where  $V$  = variance of the whole.

and  $v$  = variance of components.

It is a definition which gives quantitative and physical meaning to the widely propagated statement that in a system 'the whole is more than the sum of the parts.' (Weiss 1969). It needs to be stressed however that a physical interpretation of what makes a system is only a representation of how a system is expressed physically and is not the full meaning of what is meant by a system. Weiss argues that this nature of systems also indicates how the functions of the parts are defined by the whole. The functional parts have no meaning in themselves. The meaning to the parts and their functions is given by the whole. System in this sense has been related to the notion of a subject (e.g Whitehead 1929). From this perspective the extra that exists in a biological whole (holon) over the sum of the parts, may be the nature of subjects (subjectivity). Wilden (1980) links this to the existence of information which he defines as negative entropy which can add a non-arbitrary structure. The structure is one which can undergo morphogenesis. This implies that only organic reality can have subjectivity. However if the system is considered to be a metaphor, as for example Allen and Starr (1982) would have it, then the deduction that the non-biological physical world lacks subjectivity is avoided. This avoidance is needed if for example Maori and postmodern eco-philosophies are to be integrated with systems theory. The epistemic approach is not problematic because empiricism that views all concepts as metaphor is a respected philosophy. By contrast the rationalist assumption found in Cartesianism, which goes back to Plato (Sherburne 1966), that conceptualization has a divine link to the ontically real, as Weiss and Whitehead tried to argue for biological systems, is more problematic and widely criticised. Never-the-less Weiss' analysis of what makes a whole system over an aggregate of parts is helpful no matter what the

metaphysics are that are held. It gives a basis with which to consider what can helpfully (for pragmatic purposes) be analyzed with a systemic perspective according to the definition of a system quoted above.

#### 4.1.2.2 Designed systems.

Abstract designed systems are always involved in designed physical systems. The two are inherently related and almost always coexist. Only in purely speculative model making do they not coexist. The aim of engineering design is to explicitly develop physical designed systems according to a developed abstract designed system of coherent methodologies. This research is engaged in the process in the attempt to develop floodplain management methodology.

A designed system that involves abstract and physical dimensions can be termed an engineered system (see Figure 4.2). An engineered system seeks control of physical reality for specific goals with the help of knowledge held in abstract designed systems. As will be argued more fully later, the term 'system' is definitely only used here in a metaphorical way. Such a 'system' does not exhibit the nature that Weiss defines a system as having. The sum of the parts is greater than the whole as given by Equation 4.2 (Perrow 1984).

$$V > \sum_i v_i \quad (4.2)$$

Also the whole is strictly determined by the functions and purpose of the parts. The prototype of this is a machine. A machine is not a subject even if the physical world as a whole is considered to be so.

Construction of a designed physical system requires control over the elements in the 'system'. Scientific information based on the use of the causal metaphor about properties and ability to manipulate empower the ability to control and so help make up the designed abstract system involved. The main feature of 'value-free' objective knowledge given by modern science is that it gives 'power-over' (Habermas 1971 and Aronowitz 1988). Such knowledge gives understanding of causal relationships (mechanics) which then enable force to be applied to achieve predictable results, i.e. to control with power. The use of scientific knowledge in this way, even if it is not universally acknowledged, is the explicit purpose of a significant type of systems theory used in engineering management, cybernetic theory. Cybernetics is the 'systems science' developed to construct machines: to integrate and control the action of resources for

specific goals (Ulrich 1981).

The properties that can be manipulated in this way are extrinsic values and refer to how they can be used; i.e. refer to utility values. These defined properties are creatively connected together for the utility of human beings with the help of abstract designed systems.

According to Heidegger (1977), for elements of Nature to have their properties that are of utility to people to be discovered by people, is for Nature (or *Being* to use an English translation of Heidegger's term) to *reveal* them so as to allow itself to be considered a 'standing reserve' or resource. It implies a specific type of relationship between humans and the rest of reality, which involves control and manipulation for human utility given by Nature. Thus from this perspective, neither designed physical systems nor the use of manipulative power is inherently unethical. What is required is that the power and utility that are being given are appreciated and not *abused*. Scientific knowledge does not give absolute control (domination) anyway, no matter what may be believed. Such control is a perversion of the ethical relation that 'Being's' self-revelation is part of self-delusion. Perversion in this way can arguably be the cause of the major technological, social and environmental ills facing the world at present (see Chapter 3). An analysis of systems helps to clarify the limits of control, and hence what alternative meta-strategies for environmental management are required. Analysis that can adequately respect the limits and clarify what methods are appropriate is a fundamental aim of this research. As developed in Chapter 3, the limits are also revealed - by the immortal *gods* - and can be incorporated into systems analyses as second order feedback to direct adaptation by the system - morphogenesis. This is developed later.

The limits are clear when considering *human resources*. Human resources are compliant labour that agrees to behave in a useful way as defined by others. There are obvious limits to the ability to control human resources. As developed in Chapter 3, proactive cooperation engaging moral freedom is a better strategy and a more helpful framing of the situation. There is however no essential difference between human and non-human resources. The difference is only in the language making up the pro-active cooperative game played by the respective communities.

#### **4.1.2.2.1 Structure of designed systems.**

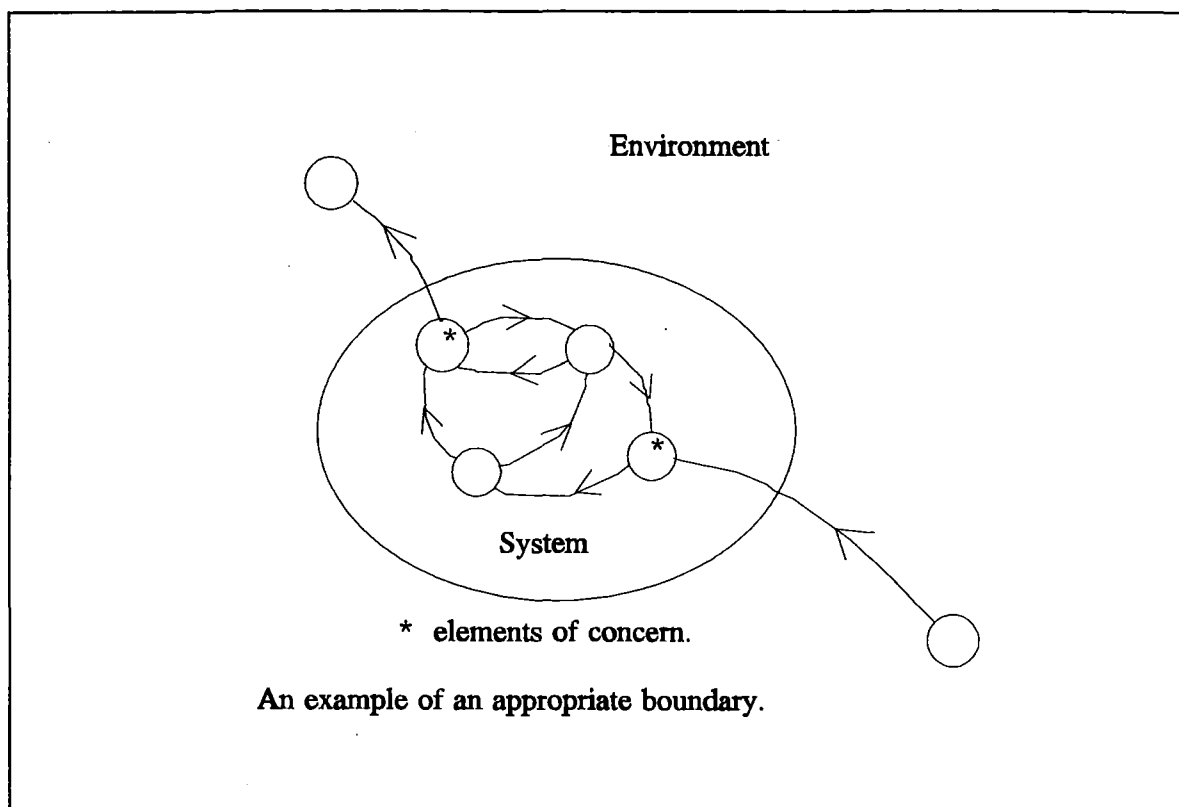
Engineered systems involve using the particular causal relationships science has isolated as pertaining to particular resources, and integrating them so that the individual resources act as a whole, for example a flood warning system. The system always



involves a combination of physical object, and human imaginative and rational thinking (the logical adherence to a designed abstract system). Often the physical objects can include sophisticated information feedback control systems, e.g. river stage levels being transmitted by radio waves to a central control which then directs public radio broadcast which in turn directs the control of human society in its institutional response to river levels. The human operators involved (distinct from the humans who design the 'system') act as compliant labour (a human resource) according to defined roles or functions, i.e. according to physical rules so as to be links in causal chains in the designed 'system'. Even when the human operators are asked to use judgement it is assumed to be written into the role. It can even be computerized into 'expert systems' to attempt to circumvent the need to use human operators to make judgements, so as to increase efficiency, consistency and comprehensiveness (see Chapter 9). Unsolicited creativity by human operators on the other-hand is equivalent to physical malfunction. It is similar to if for example radio wave interference resulted in inaccurate information being transmitted about stage levels. Human creativity can however occur in a decision by an operator to redirect the operation for perceived ethical reasons. Such potential creativity by 'human resources' indicates the need to frame the situation as one of proactive cooperation rather than control and to recognize that all utility is a gift. The end-uses and givers need to be made explicit (see Chapter 3).

Jones (1982) attempts to outline a method that insures the appropriateness of design of engineered systems in the face of limited control. Figure 4.3 (after Jones 1982; Figure 2) outlines the approach. The environment is defined as that which does not require to be included into the system. Thus the system boundary is defined by the elements which have significant causal relationships with the elements of concern (the moral community). If for example an element in the environment illustrated in Figure 4.3 was an element in the moral community of concern then it would be in the system as well. Defining a system in this way ensures that all significant end-uses and givers are taken into account (in the system). The environment consists of elements which do not have significant causal relationships with the elements in the system. Causal interactions that are not significant do not interfere with the ability of the system to achieve its goals.

Jones (1982) recognizes the possibility of failure due to non-adaptability or non-resilience in face of turbulently changing environments which may introduce new significant causal interactions. This issue is central when considering the limits to scientific design. Blockley (1980) introduces two types of error which can arise when considering systems which have been defined as Jones (1982) later outlined: parametric



**Figure 4.3;** Appropriate system boundary.

error and systemic error. Parametric error is the uncertainty which results in the quantification of the parameters which define the causal relationships that make up the system. Systemic error is the uncertainty which arises from whether or not the causal relationships defined adequately define the activity of the system. Both types of error need rigorous analysis if realistic and practical engineering design is carried out. It has been discovered that the mathematics to do so is still being developed (see Chapter 5). Also much confusion and ignorance about an adequate philosophy of science to frame the situation occurs as well, which interferes with the application of appropriate model-making in hydrology for use in floodplain management. Chapter 7 however attempts development of hydrological models needed for floodplain management, based on appropriate mathematics, to do so. What is carried out in this chapter is the development of an adequate philosophy of physical systems to base the model-making upon.

To develop an adequate philosophy of physical systems a review of the historical background helps. Modern science appears to have begun with the Franciscan monk, Roger Bacon, in the 13th century at Oxford, England (O'Connor, K 1993). His intention to develop an empirical science was to purify Christendom of metaphysical speculation, in the attempt to clarify spirituality in accordance with the Franciscan religious reform

occurring. His near name-sake Francis Bacon, in the late 16th century, appears to have used R. Bacon's work and over-laid it with the agenda of using empirical science for power over Nature (O'Connor 1993). It is interesting to note that Ravetz (1990) commented upon the paradoxical nature of Francis Bacon's work. He seemed unaware of the relation of F. Bacon's work with R. Bacon's work nor the literature concerned with it. F. Bacon's work appears far less paradoxical if the originality in his writing is seen to be only the science-as-power-over view. O'Connor's view accords with feminist literature which points out F. Bacon's involvement in the genocidal murdering of women (witch hunts) and use of a rape image to describe how science was to obtain Nature's secrets (Merchant 1989). Some theologians have also analyzed how the rape image has been central to the development of modern science and technology (e.g. Sherrard 1987). Sadly the linking of modern science to F. Bacon appears to have directed the application of modern science, and not surprisingly also soured many interpretations of the value of science. As already mentioned, it is a commonly held view among certain sociological traditions that science is only about manipulation and domination because this is how it has been used (Habermas 1971 and Aronowitz 1988). The chapter usually ascribed to the beginning of modern science involved particularly *disgraceful* language games which have been perpetuated by the scientific traditions.

The scientific tradition developed through Descartes and Newton along the lines of F. Bacon's philosophy eclipsed the original attempt by R. Bacon to nurture humility. Descartes replaced the empiricist epistemology for rationalism and claimed a divine link with the mind of God. Newton then linked rationalism to a causal universe that gave F. Bacon's attempt to control a cosmic dimension. A return to an empiricist epistemology occurred with Hume however, and culminated with the positivists who, like R. Bacon, attempted to 'purify' society from metaphysical speculation that they interpreted seemed to lead to arrogance - in their case early twentieth century Fascism (Outhwaite 1987).

However the positivists foundered on the rock of reflexivity. The logical deductions from empirical observation were not themselves empirical. They could not bask in their mind's spiritual light of the *Spirit of Truth* the way R. Bacon could (see Chapter 3). Therefore when Godel showed that their paradigm for reasoning from observation to avoid metaphysics (that of mathematics) was unfounded their agenda became untenable. Popper (1958) continued it however well into the late twentieth century through mutating it into a type of rationalism that could still reject metaphysical speculation yet not require any basis for its deductions.

Popper's critical rationalism claimed nothing more than that a scientific theory was

a belief about things observed that could not be proved nor induced - they were in no way formally linked to empirical observation. Any belief could be replaced by a better belief if it became contradicted by too many observations so that it became out of fashion. Thus his rationalism was not the strong rationalism of Descartes claiming that ideas were absolute truth, but rather the best working ideas (beliefs). However neither did Popper in anyway link beliefs to the original scientific goal of spiritual humility even though metaphysical (and sociological) beliefs were outlawed - this was purely a formal excommunication based on the argument that no natural scientific experiments could be carried out to try to disprove them. The 'spirit of truth' of R. Bacon's Franciscan spirituality played no part in it. Never-the-less Popper's philosophy of beliefs enabled him to recognise that different worlds were associated with different types of beliefs preempting postmodernism's social constructionism which has been able to integrate the 'spirit of truth' and salvage empiricism and science. Popper recognised that any notion of truth required collective corroboration of some sort ( e.g. the use of a standardized scientific method). The difference with social constructionism is that he did not see the types of world as being created through the beliefs. He appeared to consider metaphysically, and hence reflexively incoherently, that they existed in their own right - he was merely describing them. This is especially problematic for Popper because he argued also for the criterion of coherence as a requirement for legitimate beliefs.

A view with some similarity to Popper's is that of transcendental realism (Bhaskar 1978). Here language of causal interactions is used to describe the idealization of interactions that empirically cannot be verified. The difference is that an empiricist epistemology is held. The causal metaphor is used to represent to varying degrees of success trends that are observed empirically. A formal link with observation is made but without any sense of it being anything other than a descriptive image - not in any sense is it rationalism's truth. This succeeds in completely avoiding any metaphysical claims because it is linked to pragmatism and only claims that the philosophy of transcendental realism describes what must be there for science to work as it does in allowing control and manipulation. This is only one step from the postmodern position held throughout this research that the causal metaphor need not be privileged and so non-metaphysical 'transcendental' statements can be made which describe how relations other than control and manipulation are exercised through the use of other metaphors. Bhaskar (1978) privileged the causal metaphor however and made the metaphysical conclusion of transcendently occurring real mechanics because he takes a Marxist materialist position which explicitly privileges scientific discourse and the technological relations given

through science. His philosophy and tradition socially constructed his metaphysics.

The postmodern view by contrast has great versatility. Its specific application to the practice of science enables the distinction between causal and stochastic analyses to be understood in terms of systems theory. Experimentation for reductionist science requires constructing a closed system enabling only one significant parameter (postulated transcendental entity in transcendental realism) that has causal relations to other parameters to have its value altered. This method enables causal relations described by mathematics to be defined. Here a distinction from Popper's philosophy can be made. For Popper idealization of the mechanism is perfectly appropriate as it is a belief. However for the approach developed here it makes sense to try to model the fuzziness of the 'mechanism'. Thus the rigorous analysis of imprecision and the use of fuzzy logic enables the actual ability to control and manipulate to be known (see Chapter 5). Such an exercise makes no sense from a Popperian position.

The postmodern view enables the significance of non-closure of systems to be appreciated. If the environmental effects are too great then the transcendental mechanism becomes obscured or very vague and so no useful conclusions about how to effectively control and manipulate can be made. If this is because the mechanism is chaotic (three or more non-linear equations describing the mechanism) then any openness or imprecision will produce at least ranges of fuzziness. If it is simply a very open system due to a very turbulent environment then it is equivalent to chaos with an infinite number of parameters, and best modelled as completely random. In the second case a random generator metaphor is more useful than a causal metaphor. Then the analysis becomes a statistical one using probability theory modelling a completely open system that uses the scientific technique of sampling assuming no causal connection (independence).

This non-metaphysical social constructionist view overcomes any perceived difficulty with the application of multiple metaphors. For example, when looking at a river system it can be analyzed according to a causal metaphor (hydraulics) and as a stochastically occurring streamflow (hydrology); and ecologically and spiritually as a functioning god as part of an ecosystem using a functionalist and mythical representation respectively. All four are appropriate depending on the context. All four can be part of the one analysis.

Traditionally engineering did not explicitly use a causal metaphor in the application of scientific method to aid design. Craft knowledge which used pragmatism explicitly allowed for the use of any and every type of metaphor and description that might like to be applied. In general they were carried out as simply as possible and given as a list of

specifications that had proven themselves to work. Blockley (1980) makes the point that engineering design confuses the use of scientific analysis and craft knowledge, when not recognising the inherent limitation of causal scientific analysis for engineering design. Elms (1991) makes a similar point when claiming that engineering knowledge is not concerned with 'truth' as science is, but rather with goal achievement. Scientific engineering methodology has had to come to terms with indeterminacy due to extraneous effects lately however because the failure of engineering constructions is interpreted as the failure of engineering practice by most of society. Petrovsky (1985) makes the point however that paradoxically failure is still a necessary part of engineering development. Failure serves as the critical component necessary for the improvement of design. Failure provides the information necessary for the development of 'rules of thumb' about safety factors, and even insight sometimes into the causal mechanisms present which have not been open for analysis in the testing phase. Whereas this was/is socially appropriate for the craft method, it is not appropriate for the application of scientific methodology that claims to be able to 'control the forces of nature'. Engineers are in a dilemma if their craft methodology or research trials have consequences that are socially unacceptable. This is an inherent limitation in technology. It is not a technical limitation that may yet be able to be overcome as naive technocratic views would have it. Rather it is a matter of clarifying what social goals are involved and how ignorance (indeterminacy) can be handled. So just short of admitting that the engineering profession has been ironically and inextricably hoisted by its own petard, it is necessary to try to minimize the need for failure to inform design development. Insight into this challenge can be obtained by considering how imprecision related to the achievement of goals can be handled.

Blockley (1980) argues that the craft of engineering involves teleological understanding. This is the point Elms (1991) made when claiming that engineering is goal-oriented. Blockley refers to the treatment of this point by Braithwaite (1953). Braithwaite produces a description of the teleological approach in terms of the variance of the elements of the design. Braithwaite's argument is paraphrased and interpreted below.

Consider a system **b** that is defined by causal relationships. Therefore **b** is defined by the initial state and the set of environmental conditions, say **f**. Assuming the same initial conditions (i.e. the systems considered are scenarios) let **c** be a causal chain determined by a particular **f**. Therefore **c** is unique for each **f**, for each **b**.

Now consider a goal  $\Gamma$ . There may be many **c** (due to many scenarios **b**) ending up at this goal. Let  $\gamma$  be the set of **c** which has  $\Gamma$  as its end point. Therefore there is a range of **fs** (the **fs** that determine  $\gamma$ ) that result in  $\Gamma$ . Call this the variance  $\emptyset$ . A goal

can be reached by a range of environmental conditions and by a range of possible mechanisms. Let  $\psi$  be the expected possible range of environmental conditions in a certain situation being engineered. The aim in engineering design is therefore to always make sure that  $\psi$  is a subset of  $\emptyset$ . This will make sure that  $\Gamma$  is achieved.

Therefore both  $\emptyset$  and  $\psi$  have to be determined somehow. Assuming that  $\psi$  is known, and if systemic error is known, then  $\emptyset$  can be determined by measurement of the parametric uncertainty and so a conclusion is able to be reached. The required precision for achieving  $\Gamma$  can be translated as the required precision of the parameters. This is the only case where causal explanation is adequate and the systems definition given by Jones is directly applicable. When systemic error is not known then  $\emptyset$  can only be determined by subjective expert opinion: from past experiences as 'rules of thumb'; as a craft. Also,  $\psi$  is usually also a matter of expert opinion. On top of this the environment is evolving and often turbulently, in which case systemic error is also known to occur. Therefore there are situations when the achieving of  $\Gamma$  cannot be guaranteed with any certainty.

In face of the inability to achieve  $\Gamma$  with any certainty, safety factors are included which are the 'rules of thumb' necessary to make sure that  $\psi$  is a subset of  $\emptyset$ . As mentioned above, Petrovsky claims that these 'rules of thumb' for specific situations are only able to be gained from experiencing failure. Therefore there is a need to try to include the imprecision and uncertainty of systemic error into engineering analysis. A method to do this is suggested in Chapter 5.

The teleological approach outlined here summarises well the traditional engineering approach and indicates why the variance of the system is greater than the sum of the individual variances. It has to be included that engineered systems cannot be expected to maintain their structural integrity through metamorphosis in face of environmental change. They are not able to adapt. For them to adapt new dynamics need to be incorporated. This is highly relevant for the issue and social goal of sustainability. In face of indeterminacy, engineered systems based on power to control can only be expected to become increasingly maladapted. This is an example of a general system principle (Wilden 1980). Adaptability in face of indeterminacy requires the ability to be a significant functioning part of a wider whole that includes the environment of the system trying to adapt. In short, this means that the exclusive use of a causal metaphor to base design on is inadequate. To design so as to achieve the social goal of sustainability requires to also consider how to fulfil a relationship as an integral part with the environment as well. As developed in Chapter 3, this is what environmental ethics argues for. But it does not mean that engineering systems are irrelevant. Rather they need to be

contextualized adequately. What is required is the synthesis of the two types of knowledge - the nesting of the use of the causal metaphor within the organismic metaphor (see Chapter 3). For engineering systems this means explicitly incorporating feedback from the environment to change the goals associated with engineered systems if they are compromising the attempt to integrate. In other words, monitoring for degradation is required in the environment, and the feedback used to change the goal of the engineered system even if it has not yet failed. In terms of Figure 4.3 this means that the elements in the environment are considered to be part of the moral community and so feedback is constructed, which in Jones' approach extends the boundary. This illustrates how the attempt at inclusion through such feedback, is the integration into the wider system.

The success of an engineered system therefore requires the context to be considered. The institution of the feedback is within a social context as well as ecological and physical. Therefore ethical engineering design has to be considered inseparable from the institution of appropriate social processes. The social processes need to reflect the operation of a system that is adaptive. What this requires is developed when considering human activity systems. Firstly a review of how feedback has been traditionally considered is appropriate.

#### **4.1.2.2.2 Cybernetics.**

Cybernetics explicitly uses feedback and is a methodology which is a subset of the teleological approach which Braithwaite outlined. Cybernetics is a methodology that engineering has developed to try to cope with indeterminacy. Cybernetic theory bypasses the question about determining  $\psi$  and  $\emptyset$ , by not necessarily claiming to be making causal explanations. Control theory, as a subset of cybernetics, does explicitly use causal relationships however, and is able to be described with differential equations. But control theory is only possible where relatively simple deterministic relationships (non-chaotic ones) are involved and where closure from the environment exists. Generally, cybernetics is only concerned with empirically found dominant parameters, without explicitly considering the existence of deterministic mechanisms, nor systemic error.

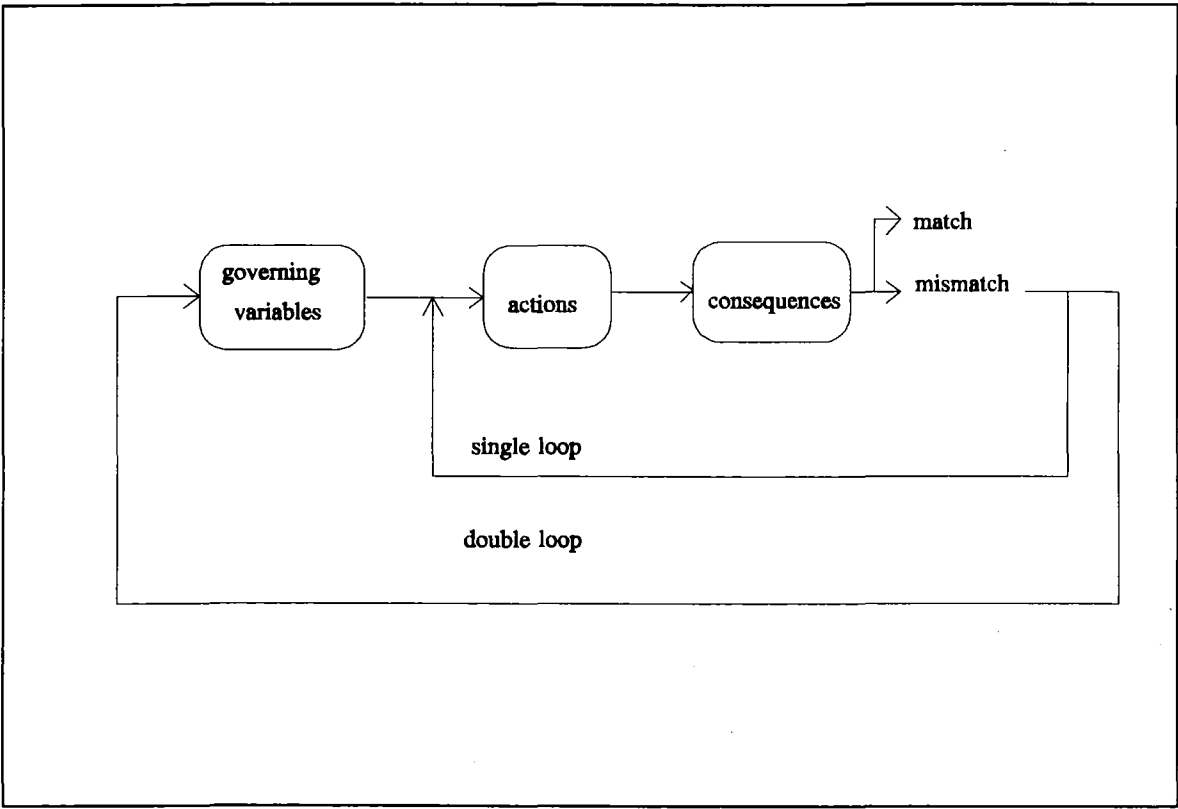
Cybernetics attempts to cope with indeterminacy by including a feedback or learning mechanism, explicitly incorporating failure (see Figure 4.4, after Argyris 1988; Figure 25.1) without any explicit reference to causal explanations. The dominant parameters are controlled by a feedback mechanism to keep the process on the heading toward  $\Gamma$  (a match). As long as stable control is possible then cybernetic method is an option. Control theory, which is based on causal explanations, is able to also predict the



response to control, by solving the differential equations describing the deterministic process. Cybernetics generally cannot do this.

Cybernetics can be more efficient than 'craft' engineering in not having to include safety factors to the same degree because there is a dynamic process to avert failure. However cybernetic methodology is inadequate if variation or failure is not an option to be integrated into the operating of the engineered system. Only certain systems can include dynamic features thus allowing feedback control. For example, a stopbank cannot include cybernetic features. Only in a long-term sense of learning from previous stopbank failures can cybernetic control be included. However of course, this is exactly what the development of 'rules of thumb' are. Cybernetics can thus be conceived of as a formalisation of the development of 'rules of thumb' and the inclusion of it into real-time operation.

Criticism of cybernetics revolves around the 'black box' approach where the actual



**Figure 4.4;** 2-loop learning.

dynamics or mechanisms are not considered (e.g Doodge 1986). An exception, whose interest is the learning process of adapting systems, is that of Argyris (1988) who criticises cybernetics for only including one dimension of feedback. He calls it *mere* single-loop

learning, and contrasts it with double loop learning (see Figure 4.4). It is well recognized by attempts to model reflexivity that a two-dimensional feedback is required (Steir 1991). Single-loop learning is unable to change which are considered the dominant parameters and hence the structure of the system - morphogenesis is not modelled nor implemented. In other words Argyris argues that cybernetics is inadequate because it does not include an awareness of possible systemic error into its operation. This makes cybernetic theory unable to overcome the inherent difficulties of making 'rules of thumb' judgements when there is a turbulently changing environment. Unknown systemic error includes the need to change the goal of an engineered system because of feedback about its effect on its environment. In terms of Jones' (1982) argument, the environment becomes part of the system therefore feedback about wider consequences to aid integration into the wider system is required. As developed in Chapter 3, this is a second-order feedback. Because integration is conceived of as synchronic relationships the analysis of the situation is not carried out causally but through the use of an organismic metaphor. Thus appropriate goals for engineered systems are defined in terms of the functional role they serve in the wider system. Structural evolution of the engineered system is assured of adequately incorporating systemic error due to a turbulent environment if functional integration with the environment directs what the goals are that the system is attempting to achieve. Only then are the *gods* and the 'spirit of truth' directing *graceful* evolution. For example, if the environment is very turbulent the goals will not be able to be very adventuresome as no stable integration is viable, and so systemic error will not be an issue. The *gods* in such situations are saying to not interfere with other beings in the communities: utility is not being offered.

#### **4.1.2.2.3 Types of designed systems.**

Blockley (1980) has outlined a distinction that can be made between types of designed systems. Some designed systems within the realms of possibility are tested for the influence of environmental effects. The validity of the design will then be analogous to a well-corroborated scientific hypothesis as defined in Popper's critical rationalism. No metaphysical claim about the 'truth' of the design is made. Rather it is believed to be sufficiently safe and useful. Thus prototypes are constructed, and only after what has been considered the showing of sufficient resilience by being tested under different environments, do production models go to work for the purposes for which they are intended.

Other machines are however one-off constructions. They cannot be tested before

productive implementation. 'Subsystems' of the whole 'system' may be able to be tested and may even be 'off the shelf' components. For example a flood warning system will use marketed radio transmitters. But the overall operation cannot be tested. This is problematic because the expected total risk, and hence lack of safety is in general given by Equation 4.2. The calculated summation of the risk of the parts is less than that of the whole system (Perrow 1984). It is important for risk analysis techniques (see Chapter 6). This is exacerbated when there are human operators involved. Human 'error' is considered to be the major contributor to the collapse of systems (Perrow 1984). To believe or expect a machine to behave as a biological system where  $V < \sum v_i$ , is to invite disaster and have a falsely exalted understanding of engineering capabilities. That  $V > \sum v_i$  is empirically verified (Perrow 1984) is evidence for a general law of ironical results (or counter-productive results or inevitable failure) for engineered 'systems'. Busch (1989) has argued for such a law in agricultural engineered systems. Because of this danger, the use of the term 'system' in this context may be a mistake as it suggests and nurtures false understanding about engineering abilities. Wilden (1980) argues for the use of the term *structure* for this type of construction. He reserves 'system' for a structure that incorporates information about the environment in such a way that it has the ability to adapt so that systemic error is incorporated into structural evolution: it can undergo morphogenesis.

#### 4.1.2.3 Human activity systems (HAS).

HASs are distinctions made of social interactions explicitly considered to be structures (compared to systems to use Wilden's (1980) terminology). Checkland does not use this terminology however. He uses the terminology of *society* and *community* to make the distinction. A HAS is a society - a rationally constructed goal-oriented 'structure.' A community is a natural system. Thus a community is an immortal *god* but a society is not. The distinction between community and society is a long-standing one in sociology (Fletcher 1972). Giddens (1984) points out however that a paradox occurs in the making of such distinctions because the interpretations affect what the social relationships are. The social paradox that results is an example of what is termed the *hermeneutic circle*. It is an interpretative method that uses the paradox that interpretation of a part (text) requires interpretation of the whole (context), and interpretation of the whole requires interpreting the parts. The method involves iterative learning going from the parts to the whole and vice versa. The paradox is that sociological interpretations of society or community based on analysis of the interactions of the parts can result in the

parts relating differently because the interpretations held by the actions which direct their relationships have been influenced. The result may be the need for a better sociological interpretation and so on... Thus HASs always have a normative aspect to them that may be implicit or ideological.

Checkland recognizes that HASs involve people having particular perspectives, but fails to recognise that HASs are also particular perspectives, and so fails to recognise the paradox. His unreflexive position is an example of naive relativism summed up by the reflexively incoherent statement 'all is relative' (Seung 1982 and Lawson 1985). If the statement is true then it negates itself. The failure to recognise the naivety of such relativism leads to those analysing society to assume privilege in interpretation and hence a privileged role in the normative evolution of society. That social scientists (especially economists) have taken on this 'priesthood' role is much lamented (see Chapter 8). The result is ironical because much of sociological analysis is concerned with criticising and trying to transform authoritarian structures that are perceived as unjust because they privilege particular groups.

To avoid the paradox and irony of the peculiar role sociologists and social scientists have, postmodern sociology attempts to be reflexively coherent. Society here is interpreted as the acting out of a language game that all participate in; sociologists no less nor more than others. Similarly all actors equally are making interpretations that participate in the language games. The term *game* is used because the particular interaction could be otherwise. Creativity is at 'play'. The point is that it is collective. The game is *socially constructed*. That games are played indicates that 'the whole is less than the sum of the parts' in an HAS in contrast to a system where the whole is more than the sum of the parts. The parts are able to create alternative 'wholes'. Any game is a constraint on the possibilities. As developed in Chapter 3, the language of signs mediating the social construction of the game is best considered another being; an immortal god synonymous in *interbeing* with the community it nurtures. It is this which is more than the sum of the parts and is the system.

From this postmodern position, interpretation of structure is but another creative input into a game. To analyze the dynamics of society cannot then be carried out by making interpretation of structure - not even an evolving one as a process of history. Postmodern 'historical analysis' points out that seeking historical truth is an attempt at essentialization of social construction while being a social construction itself to legitimate certain present practices. Postmodern writers prefer to engage in 'genealogy' which seeks to reveal the social construction in evolving language games (Smart 1985). Belief in

history as an entity is indicative of how it is a meta-sign for immortality which attempts to have a role in modern thought similar to that of immortal gods of community (systems) in Maori and Heideggerian thought. Therefore what is required is a very fundamental shift from a historical (diachronic) perspective to analysis of the system (synchronic relations) as language in terms of language in reference to itself. The basis for this requires to be prior to language however. It is a step further than genealogy. It is the step of reconstruction after the deconstruction carried out by genealogical analysis (Soderqvist 1991). The reflexive bind this involves when trying to communicate it has been explored by Woolgar (1988). However the approach taken in Chapter 3 is coherent. It simply has to be decided what metaphors are being used, and when they are appropriate. This means that sociological analysis of structure (HASs) are an expression of a natural system. The basis is not merely a creation of language. They are in response to some functional requirement of the natural system humans (including sociologists) are living in (Ravn 1991).

However the analysis of natural systems according to an organismic metaphor incorporating functions defining purpose to the creation of an HAS, is in itself a creation of language and hence a HAS; but rather one analysing systems. Here once again is the hermeneutic circle, but one where the concepts used are coherent and reflexively and explicitly incorporate the reflexive hermeneutic circle iterative process. The role of the sociologist can be to help define what feedbacks and reinterpretations that occur may mean, and how they can be incorporated into the language game so as to achieve the goals that the community collectively wants to achieve. It is an example of recognizing the second-order feedback directing how the system can evolve so as to be sustainable - live in the life of the *gods*. A methodology to do this is developed through the remainder of this chapter and subsequent chapters.

#### **4.1.2.3.1 Creativity and indeterminacy.**

From the postmodern view developed here, what is referred to as indeterminacy is also able to be interpreted to be creativity, freedom and the intelligence of individual beings existing at different levels - mortals and gods. GST meta-theory which has attempted to incorporate creativity into a coherent worldview is helpful to appreciate the dynamics involved. The meta-concepts used in GST according to Checkland (1981) are: emergence, hierarchy, control, communication. At each level in the *hierarchy*, new features and hence descriptive concepts *emerge* as being appropriate. The higher levels are seen to *control* the lower levels through *communication* using a feedback network.

Creativity is incorporated into the theory by considering that any level in the hierarchy is able to control the lower levels. Creativity is bounded however by the control of the yet higher levels. Thus creativity is able to be incorporated in this way at all levels. See Wilson (1985) for a view which sees creativity operating at all levels of all natural systems.

Whitehead's (1929) process philosophy is another example of a hierarchical view which perceives creative beings at many levels. He points out that being is often linked with consciousness and argues that it need not be the case. As mentioned in Chapter 3 Whitehead rejects the Aristotelian view of distinct substances, and so allows hierarchical interbeing to be appreciated. Also already mentioned, this has been taken a step further by Horowitz (1992) and Martin (1993) through development of the Buddhist notion of *interbeing* which enables hierarchically existing conscious beings to be appreciated in keeping with Maori and Heideggerian thought, along with popular interpretations of Lovelock's (1987) Gaia hypothesis (e.g. Joseph 1990). Lovelock's interpretation did not however even use a hierarchical analysis. Reductionist symmetry through use of a causal metaphor was retained.

Whereas Checkland's systems typology uses the GST hierarchical approach for natural systems, thus enabling creativity to be appreciated, he did not do so for HASs because he failed to perceive the reflexive relationship, as already mentioned. Therefore Checkland implies that creativity is bounded in non-human social systems in a different way to that which it is in a human social system. This is not able to be substantiated and a more coherent null hypothesis is that human and non-human social activity is only different in degree and not of type, and therefore the bounding is of the same type. Therefore non-human social systems can be considered as belonging to the same type as HASs and vice versa.

A coherent approach that synthesises the GST hierarchical meta-concept and the insights into HASs is required. This can be begun by considering the two levels recognised by Checkland as existing above that of organisms: social structures defined by 'language games' and transcendental systems. HASs are concluded to be a product of evolution as much as non-human social systems and therefore according to Checkland's typology are a type of natural system. Checkland in fact acknowledged this aspect of the paradox when characterising situations of human relations as both HASs (societies) and natural systems (communities). The two higher levels clarified are required to be seen to act in a mysteriously dynamic way which GST does not represent adequately. The mystery is an expression of the way ethics is an expression within language games in

response to direction from the grace of the spirit of truth in the immortal life of the gods as feedback systems. The difficult question of what should guide reality construction is at stake (Ravn 1991). A suggestion is proffered in later sections based on postmodern understanding of reflexivity.

Engineered systems become part of this as they are an expression of human creativity and so are bounded by the two levels higher than human organisms as well. The resulting interaction between language games, transcendental systems and hence ethics, and engineered systems or technology, is the fundamental dynamic which an adequate understanding of engineering requires so that engineering management can be carried out responsibly (revisit Figure 4.2). This research attempts to add understanding about this for floodplain management.

What are left to clarify are the processes that the levels give rise to, and how the notion of beings other than organisms can be incorporated. Checkland's view of HASs is unable to address it. As mentioned several times, languages can be considered to be an immortal being as can all open systems akin to ecosystems and an undefinable transcendent Being/God. If reality is defined according to such a hierarchy of open systems it is consonant with the idea of hierarchy of interbeing. The difficulty this leaves for the consideration of social relations is that traditionally sociology has considered structures and so for epistemological reasons where multi/inter-disciplinary research is engaged in this is required to be appreciated. However it fails to appreciate the overall postmodern approach which reflexively considers systems. Never-the-less postmodern sociology is beginning to, and a development appropriate for decision-making and engineered systems is proffered by this research. It is based on an image of reflexive spheres. First however it is necessary to review the traditions in sociology so as to be able to incorporate them where appropriate. The various traditions can be interpreted and evaluated in terms of an organismic metaphor as to what function they can have as information to guide adaptive behaviour. A radical constructivist approach is used to carry out the review (see Chapter 3).

#### **4.1.2.3.2 Functionalist social theory.**

Functionalist social theory bases its analysis on the attempt to fulfil instrumental values through using an organismic metaphor. The theory analyses society as if it were a designed system, i.e an engineered system. Therefore humans are considered as instrumental means. Checkland argues that this social theory fails to recognise that the term 'system', and hence 'function' are being used metaphorically. This begs the

question however as to what the consequences of this are. Checkland later on concludes that he is concerned with overcoming the abuse of power. So this gives a clue. However power is an interpretation due to the use of a causal metaphor and so the situation is a confused one of mixed metaphors. What is required first is an analysis of how power arises, and how a causal metaphor can be appropriately used in conjunction with an organismic one.

Power arises according to Wilden (1980) when negative (second order) feedback to the system is denied. It is a type of systemic neurosis. An organismic metaphor is appropriately applied when integration occurs as a level in a hierarchy. Therefore the appropriate use of an organismic metaphor can make negative feedback explicit because integrity of functional roles is what negative feedback seeks to maintain. Therefore what Checkland is pointing to is that engineering of a social system according to an organismic metaphor as functionalist social theory can lead to the expression of power that is the denial of integration because it is imposed without receptivity to negative feedback. Ironically however, to the extent that power succeeds in its coercion then 'functions' are real; but not sustainable! The main consequence of this is that 'function' can change through human creativity, therefore it is not a transcendental reality, in the sense of a universal scientific law. Function can be imposed, paradoxically, by considering that it is a transcendental reality when it is not. Functionalist social theory making such claims can do so. Even an empirically disproved functionalist thesis can cause the creation of previously non-existent functions through the implementation of the false thesis concept by the imposition of a 'language game' by technical elites using power of coercion. This is how social theory can appear in social praxis as 'self-fulfilling-prophecies'. This is why it is so important to have adequate social theories for planning and management.

In response to the abuse of the organismic metaphor, Ferré (1989) who is a supporter of the use of the 'organismic metaphor' as it is used in functionalist social theory, never-the-less recognises its limitations. He points out that several times when it has been believed of human society that the whole is actually more than the sum of the parts, inhuman policies were implemented in the name of the whole (the nation/humanity) at the expense of the parts (minorities and individuals). Ferré cites Fascism and Communism as examples. This concern of Ferré is typical of postmodern theorists. Denzin (1991) puts it just as strongly by saying that the nineteenth and twentieth centuries have had enough 'terror' from the seeking of social holism. However a society (where the whole is less than the sum of the parts) as a construction by organisms within it does have utility value to help enhance the intrinsic values of the organisms within it, and other



intrinsic values also. What is required is that the social construction of it be recognized.

There are two variations of functionalist theory which are important for systems research into floodplain management:

(a) Functionalism.

(b) Technological society as a functional differentiation of labour.

#### **4.1.2.3.2.1 Functionalism.**

Functionalism was originally directed towards the study of traditional groups. Here the whole is considered to be an integrated activity due to the interacting of unintended consequences of activities (Fay 1975). Integration in traditional groups is sometimes seen to be due to 'symbolic violence' or 'ideological false consciousness' where power is masked by claiming its naturalness (e.g Flood and Ulrich 1990). This is the view held by the Marxist and critical social theory traditions. Integration in traditional societies is also seen however to be due to 'transpersonal' influences (e.g. Neumann 1959 and Fox 1990). This is the view held by the Jungian school of Analytical Psychology and Deep (transpersonal) Ecology.

Therefore both the existence of bad and good integrative effects are recognised, and emphasised by different traditions. Critical social theory (e.g. in Habermas 1970a) emphasizes the bad aspect and attempts to seek solutions through rationality to achieve liberation for individuals from oppressive division of labour, or functional differentiation within society. When it is seen as good, integrative effects are seen as the unconscious expression of ethical behaviour based on moral intuition. Tonnies (see Fletcher 1972) develops this view and is where the sociological use of the term 'community' originated. Checkland (1981) attempts to integrate these virtues of 'community' as natural system into systems research.

The dichotomy can be overcome by recognizing that there are higher level actors involved; language and higher communities, as well as the transcendental sacred. Language can mediate symbolic violence (e.g. the functional social theory that Checkland critiques) as well as constructive goal setting (e.g. the liberation through the use of moral freedom Habermas seeks). The Sacred can inspire moral intuition and the creativity within language to organise sustainability through integration into the life of the immortal gods, as developed in Chapter 3.

#### **4.1.2.3.2.2 Technocratic society as a functional differentiation of labour.**

This is an example of the functionalist social theory which is usually attacked as being inadequate (e.g. Checkland 1981). Luhmann (1990) has been a sophisticated protagonist and characterised advanced technological society as a functional system without a centre. Advanced technological society has functional groups who are self-defining their roles: there is not a hierarchical 'top'. Previous societies are characterised as a hierarchical structure with a managing class determining the functions of those 'below'. The whole is a creation of the managing class. Luhmann argues that such an hierarchical view was/is an attempt to solve the inevitable paradox in human society about the inherent arbitrariness of any social structure. Luhmann approaches the situation reflexively but he describes advanced technological society as another arbitrary human creation also seeking to solve the inevitable paradox that is doing it better. He argues that the functional entities acting as self-adaptive and self-centred instruments for the development of the productive enterprise of modern technology enable the efficient creation of wealth. Also because the whole is non-centred, it has a resilience or adaptiveness not found in hierarchical structures (Chislom 1989). The non-centre gives a way to cope with complexities, and hence risk, by introducing loose coupling (see Chapter 6). A hierarchically structured society does not have the same adaptability. Emery (1981) argues the same point when arguing against the non-adaptive ideal of a rigid social structure. Both Luhmann and Emery argue for the superiority of a system. But the system Luhmann describes modern technological society to be does not have the ideals Emery argues for. The difference is illustrative of the difference between modernity and postmodernity and how second-order feedback is handled.

Emery (1981) in analysing adaptive systems in turbulent environments argues that fundamental changes in the meta-ideals of modernity are required. In agreement with Luhmann he argues that an adherence to a meta-ideal of 'truth' as a naturalistically defined knowledge will lead to poor adaptivity because non-creative conforming aggregate-collectives result. Conformity loses its ability to be successfully adjusted to its niche as the environment inevitably changes. But in contrast to Luhmann he argues that successful co-evolution requires rather the adhering to the ideal of 'nurturance'. This is the seeking of dialogue and learning through creative interchange, where each individual takes responsibility for the creation of their own worldview. Emery argues that this ideal implies a 'fundamentally different experience of the world: nature is taken not as an object of domination and exploitation, but as a "garden" which can grow while making human beings grow.' Emery contrasts other ideals as well (see Table 4.1).

Modern	Postmodern
Truth	Nurturance
Plenty (wealth)	Homonymy
Good	Humanity
beauty	beauty

**Table 4.1;** Modern and postmodern ideals (i).

‘Homonymy’ refers to the improvement of choice or in other words reflexivity bringing freedom through transcendence. ‘Humanity’ is chosen over ‘good’ so as to make clear ‘good for whom?’ ‘Beauty’ is defined by Emery as a state of higher potential for choice, i.e. it has higher diversity and so is an environment allowing more scope for successful adaptations by systems interacting with it. - the bio-diverse immortal life of the gods.

A second contrast is also outlined by Emery (see Table 4.2). They are significant as the postmodern set agrees with Weare’s (1991) analysis of human capacity for virtue (see Chapter 3).

Modern	Postmodern
Achievement	Self-actualization
Independence	Interdependence
Self-control	Self-expression
Endurance of distress	Capacity for joy

**Table 4.2;** Modern and postmodern ideals (ii).

Luhmann’s ideals are modern according to Emery’s typology. Ellul (1980) defines modern technological society as a system in keeping with Luhmann but argues, in keeping with Emery, that it is not a good system. He agrees with Luhmann’s analysis of the non-centred evolution of technological society, but argues that integration into a whole in the technocratic society involves ‘symbolic violence’, which is being ever increased by the use of computers to create a universal language game. In agreement with Luhmann, Ellul

sees a loosely coupled 'system' that is adaptive and autonomous. Unlike Luhmann, who sees positive features to this, Ellul sees it only as the source of the anxiety, alienation and meaninglessness experienced in society. Therefore he agrees with Emery's view that ideals have to change. Specifically, the seeking of wealth is seen to focus on competitive manipulation for survival for no purpose. Values associated with growth that emerge through reflexivity of the individual are denied. The system may be reflexive, as Luhmann says, but individuals are denied to be so. Thus growth is hindered; intrinsic values are not respected. Thus technically the claim that technological society is a system is incorrect because the environment is not being integrated with. Ellul (1981) actually uses the image of technological society as a cancer, which when malignant spreads, having apparent life and growth, but which is in fact destroying life and eventually its own life source - the opposite of an immortal god's life!

Within technological society pressure groups are controlling and coercing in self-adaptive and self-centred competitive development of technology, in the belief, or under the pretext, of a utopia that will come from technological development in fulfilment of the ideals of modernity (see Chapter 3). Crane (1987) provides empirical evidence for the argument that the adaptive, self-centred entities making up the non-centred social organisation, are the technical elites, e.g. the engineering profession. It is these self-centred (professionalised) technical elites which are creating the modern 'language games' performing the coercion and causing the social and wider ecological degradation.

Marx was critical of the situation (see Bannet 1992) but as Ellul (1980) argues, attempts to implement Marxist theory to replace the market mechanism for resource distribution, did not change the utopian vision of technology and so the problem has not been solved by Marxian social theorists to date. In fact any utopian vision can be expected to be maladaptive because it contrasts with the centrality of adaptation as the ability to change vision. Utopian visions have notions of equilibrium and sustained trajectories which can only be expected to be the inspiration (sic) for system failure; social and ecological (Wilden 1980). Emery's ideals ironically de-centre modernism's utopian ideals!

Interestingly in earlier work Luhmann (1974) contrasts the employment of power as found in the imposition of technology to the development of trust. However he distinguishes between simple trust and reflexive trust to show how trust can itself be used ideologically in the opposite way to which Emery conceived to mean in the context of nurturance. Luhmann (1974) defines the trust found in communities as simple, and that found in technocratic societies as reflexive. He argues that reflexive trust is held between

the self-adaptive corporate entities making up technocratic society. He sees reflexive trust as trust for how it helps oneself, rather than being due to the development of inter-subjective relationships found in community. He also makes a distinction between two types of reflexive trust: 'trust in trust' and 'trust in distrust'. Technical elites, e.g. engineers, try to develop 'trust in trust' so that they are 'trusted' by the public whom they are simultaneously exercising power over. The utopia they promise, through the development of technology, is the rationale by which this 'trust' is attempted to be developed. 'Trust in trust', according to this interpretation, can be called an ideological trust because it uses 'trust' to mask hidden self-serving motives of maximising self-advantage. It can also be described as a patronizing process. 'Trust in distrust' on the other hand, is not ideological trust masking self-serving motives, but rather the unabashed open exhibition of the maximising of self-advantage. In contrast to the notion of reflexivity bringing trust between people, as developed in Chapter 3, Luhmann assumes that simple trust is naivety and assumes that self-interest is the essence of the situation. The approach developed in Chapter 3 would invert this by claiming that self-interest is the perversion of trust which should be gained through deep reflexive awareness as the basis for ethical activity. Overall Luhmann is describing trust between those who are exercising power over others: the trust necessary to succeed in corporate domination. Wilden (1980) pointed out that it is a corporate expression of the market that is counter-adaptive because it is based upon denial of feedback from the environment. Ideologically the trust Luhmann espouses is an example of exertion of power contradicting the distinction between power and trust that Luhmann (1974) makes. The reason is because Luhmann does not recognize power expressed through ideological coercion.

Galbraith (1983) outlines a typology of power which clarifies what different types of power are that occur so as to appreciate the subtlety. They are 'condign' power which is explicit authority involving punishment, 'compensatory' power which involves reward for behaviour wanted to enforce and 'conditioned' power which is inherent within expressed worldviews. This typology enables the 'progression' from a hierarchical society to the modern de-centred one of autonomous professions to be interpreted as a shift from the use of condign power to compensatory and conditioned power. To define institutions which express only compensatory and conditioned power to be using trust rather than power is an example of ideology that can be expected to occur in functionalism, as mentioned above.

Therefore in conclusion, in contrast to Luhmann's support for it, if the aim is to achieve sustainability and bio-diversity then modern decentralized society is not an

improvement over hierarchical structures because the moral community that needs to be integrated with is even further obscured.

#### **4.1.2.3.3 Phenomenological social theory.**

Checkland defines the social milieu as a HAS according to the phenomenological tradition of social science. Phenomenology as a tradition is considered to have begun with Kant (see Mingers 1990). Each person is assumed to have a unique world view that is an interpretation of reality (Bruyn 1970). Neither philosophical realism nor idealism are assumed (Mingers 1984). What has been assumed however in twentieth century phenomenology since Husserl introduced 'transcendental phenomenology' (see Seung 1982, Lawson 1985 and Jalbert 1985) approaches is the ability to distinguish between pure perception given as the basis for the empirical sciences, and the symbolic which explicitly refers to something else, e.g a text. Different interpretations are said to arise because each person is said to give different meaning to what they perceive. Meaning is the central concept but concerned with these two types: of pure perception, and the referential. Holding this distinction creates a meta-worldview to be held in the attempt to be coherent. It enables individuals to consider the worldviews they explicate to be an expression of symbolic meaning. It is unclear however what they as a symbol actually refer to (Dreyfus 1984).

Traditionally among phenomenological thought the issue is more fundamental than that and the meta-view developed above had not been assumed. Some, following Hegel's insistence on reflexive coherence, argue that all the meaning comes from the persons giving meaning, while others argue that reality itself has meaning in itself that is discovered, for example in the discovery of intrinsic values. Nietzsche has been very influential and applied a reflexive critique to any idea of meaning in itself, and developed a view that all meaning (including his own) is projected onto reality, and so is contingent (see Lawson 1985). Truth can only be a social construction and all concepts are metaphors - images of sense perception projected onto different situations (Danto 1965). This notion of projection of meaning he summarized as 'the will to power'. Meaning is interpreted as inherent power because it is projection which has an effect through the social construction of reality that accrues from it. Because of the interaction between subjects exerting such 'will to power', reflexive dynamics of a type of 'hermeneutic circle' arise. For Nietzsche it was a cosmic hermeneutic circle with all creatures participating. He summarised the cosmic dynamic as 'eternal recurrence'. It can be interpreted as natural systems having an inherent reflexivity creating the information (forming systems)

and dissolution and/or transformation depending on whether they are mortal or immortal. However Nietzsche did not conclude fatalistically or nihilistically. He saw the possibility of individuals being able to reflexively become aware of 'eternal recurrence' so that they were not a victim of it. Such reflexive transcendence he called the state of being a 'superman'. Jung (1974) has termed it 'individuation'. It can be interpreted as awareness of eternity and the immortal life of the gods achieved through integration into natural systems (see Chapter 3). Therefore paradoxically Nietzsche concluded that all meaning is discovered, in contradiction to his starting point. He did not attempt to resolve the paradox. It has left some wondering why he did not develop a spirituality however (e.g. Malik 1974). McGowan (1991) and Weaver (1995) suggest that the reason is because the Cartesian essentialist view of an autonomous self was maintained by Nietzsche which made the transpersonal or sacred impossible to conceive.

It took the work of Heidegger to attempt to resolve the paradox of Nietzsche and to introduce a spirituality of Nature. Heidegger rejected the Husserlian transcendental phenomenological method by pointing out that worldviews are an abstraction (Dreyfus 1984). He returned toward the Kantian position to consider the role of fundamental concepts, but without considering them to be transcendental and hence absolute (Rosen 1991). He developed the notion of the individual as ontological rather than Cartesian, where fundamental concepts shaping reality (self and world) evolved (see Chapter 3). The ontological process of growth was seen to be an inherent expression of systemic reflexivity at all levels up to the cosmic that all individuals participate in. Individual awareness is Being's awareness of self and was seen to inherently come into existence as 'eternal recurrence' was discovered.

Wittgenstein took a different approach to resolution of the paradox by insisting that language should only be used for practical purposes (Lawson 1985). The language game is simply to be reflexively accepted as a given, and the task is simply to get on with the job of making better games, without consideration of metaphysics. Heidegger in contrast tried to think about what creates the dynamic of eternal recurrence so as to give guidance about how to be practical. Heidegger attempted to define the normative whereas Wittgenstein did not. *Being* is seen as inspiring the *grace* which transcends subjects and is the dynamic giving ontological growth of all systems at all levels. Heidegger maintains a non-naturalistic holistic principle akin to religious thought (Zimmermann 1993). It is helpful as it enables imagery based on GST to be used as an over-metaphor of the social construction process that can give normative direction as to how to fulfil the ideal of sustainability or adaptability because an organismic metaphor can be nested within it.

Heidegger in later work crossed out the word Being when he used it in the attempt to explicitly emphasize the point that it was itself being used as a metaphor (Lawson 1985).

The over-metaphor can be construed as a set of reflexive spheres. This explicitly uses the imagery which Jung (1974) argues is most appropriate for meditation. He argues that it should be an image that is mandala-like, involving concentric circles. This approach enables the levels of GST to be included but without a hierarchical image being used (see Figures 4.5-6).

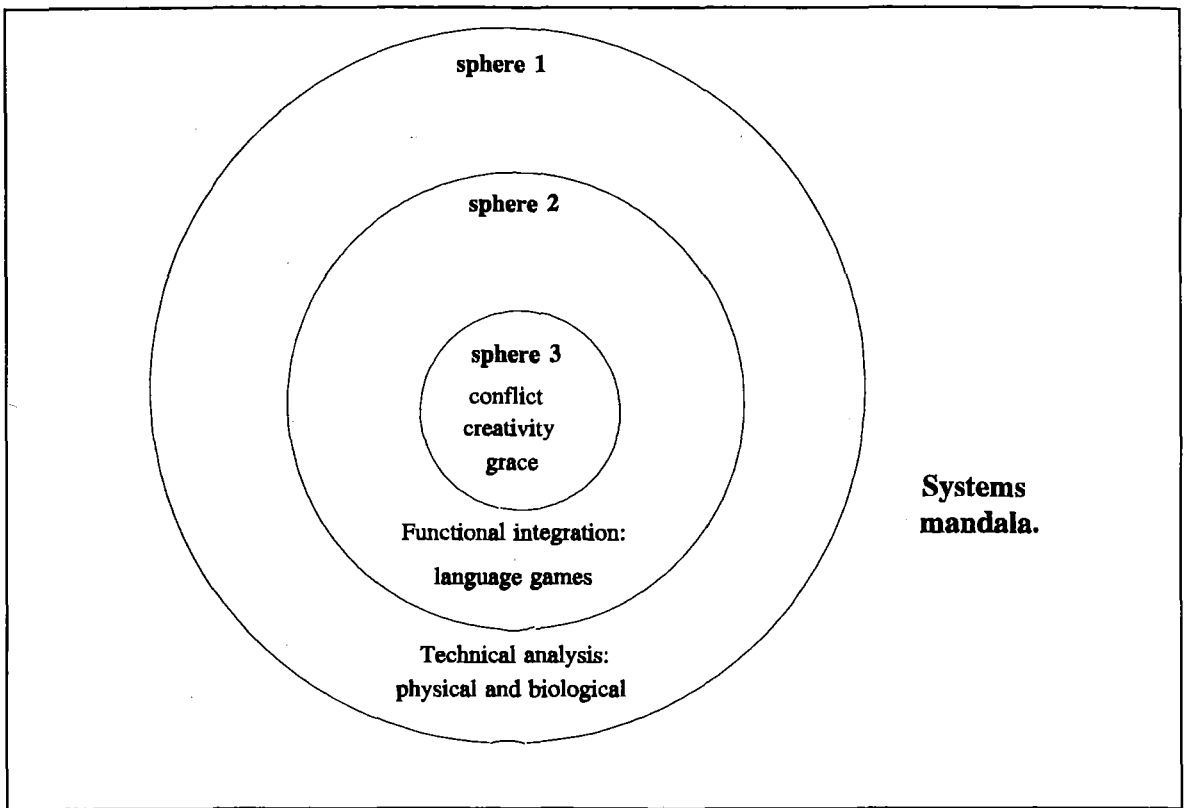
Before commenting directly upon the figures, it is helpful to consider Derrida who also criticised the transcendental phenomenological distinction between pure perception and the symbolic. He criticised it because of the requirement of reflexive coherence which made anything that symbols were supposed to be referring to remain within the text. Thus only pure perception existed, and accordingly Derrida called himself a 'radical empiricist' (Lawson 1985). Any evolution or dynamics can only ever be within language or signs which create worlds for people, but the more they are claiming to refer to something outside of the text itself the more alienation they create. Thus metaphysical concepts are seen as empty and creating absence and alienation. Heidegger argued the same but less directly.

From Nietzsche's perspective, metaphors or concepts are expressions of the 'will to power' and only ever projections. Only in deconstructing all projections does individuation of the 'superman' occur. This is fascinating because it can be interpreted as finally achieving what R. Bacon set out to do when initiating the modern empirical science project seven centuries ago.

Post-structuralism has taken up Derrida's views and noted similarity with Hegel's solution that reality is impersonally produced through the interacting of concepts (Mohanty 1984 and Williams 1992). However post-structuralism has interpreted it in terms of ironies of knowledge rather than metaphysically as Hegel did (McGowan 1991). One irony is the Hegelian realization of never having a world (language game) which works fully or is final. Tension is an inherent aspect of existence (e.g. Gutierrez 1971). This agrees with the notion of requiring second order feedback to maintain integrity. The other is the irony of always being alienated from Being, and hence the need for *grace* that is transpersonal to bring us to individuation transcending concepts - and openness that Buddhism calls no-mind (Curtin 1994). The second elucidation of irony completes Heidegger's work as it resolves the paradox of attempting to describe non-naturalism.

The reflexive sphere imagery enables mythical imagery to be appreciated as the necessary context for normative discourse. For example the pole that is transcendental in

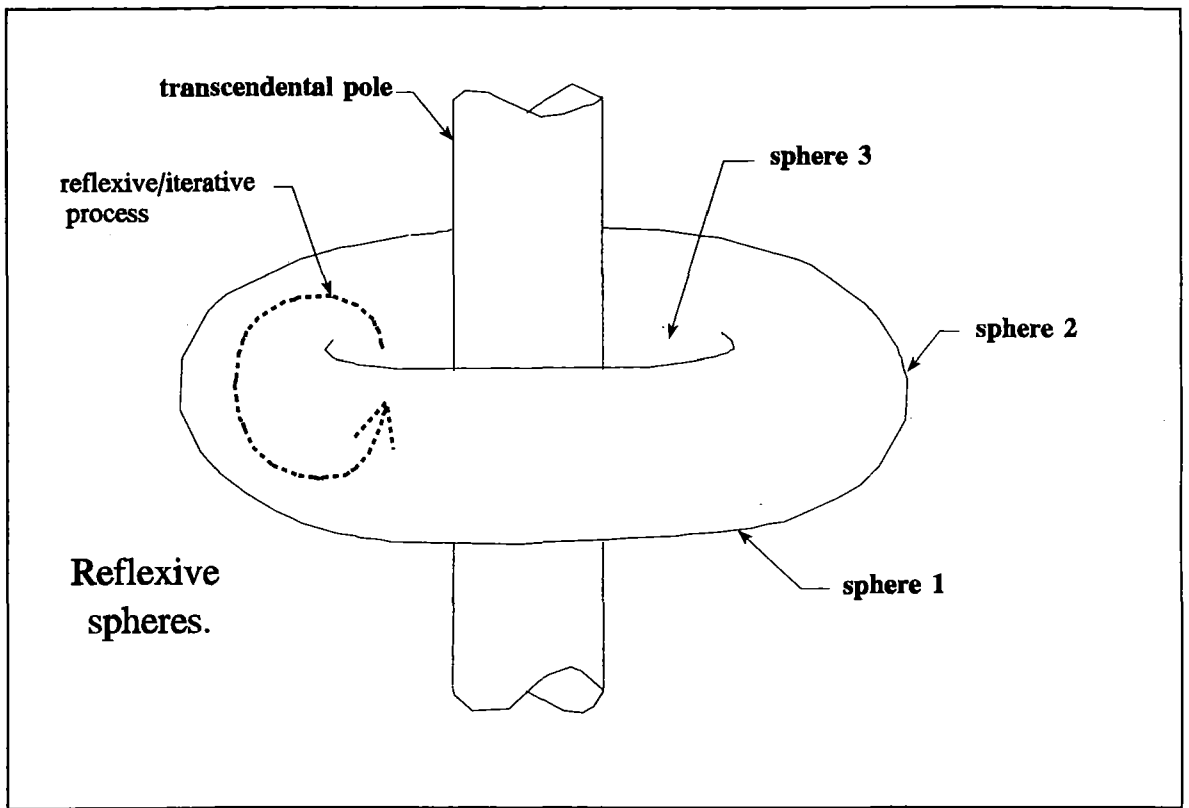




**Figure 4.5;** Systems mandala.

Figure 4.6 is a cosmic hoop that all cultures hold to according to an Amerindian myth (Niehart 1972). In Christian theology it is the transcendent Father from whom the Holy Spirit as a wind, or spring of life-giving-water, comes forth to bring growth that is Christ (incarnate God) revealing the Father in nature (e.g. Maximos 1981). In traditional Maori spirituality it is the Void (te Kore te kore) which is the source of all life (Gray 1994). For Buddhism it is also the Void (Govinda 1960). Maori tradition also terms it the poupou (centre pole) however when referring to its manifestation as a god or presence in Nature (wilderness). The poupou is considered to not only give personal balance through providing a sense of belonging to a community and place, but also 'cultural safety' because it defines the limits for interaction with the environment - second-order feedback (Biddle 1995).

In phenomenological social science the meta-distinction between pure perception and the symbolic is however maintained, and a system is defined using 'pure fictions' that describe 'ideal types' to be constructed as symbols expressing dominant worldview characteristics (see Fletcher 1972). These ideal types are imagined to interact to form a structure or system. The acknowledged purely fictional nature of them means that the resulting system is seen to only be the average activity. Functionalist analyses reviewed



**Figure 4.6;** Reflexive spheres.

above can be interpreted as specific cases of such constructions (e.g. Ellul 1980). Non-ideal activity results in the 'system' exhibiting fluctuations about the mean. The same interpretation has been applied to the phenomenon of physical systems (see Chapter 5 and Prigogine and Allen 1982).

Because of the reflexively incoherent distinction between pure perception and the symbolic, postmodernists have looked back to earlier attempts to gain coherence before this meta-distinction was made. Therefore they have returned to Nietzsche and taken up the work of his commentators; Heidegger, Wittgenstein and Derrida. The result has been 'language game' social theories.

#### **4.1.2.3.4 Language game social theories.**

These theories are post-structuralist (post-Wittgensteinian and Heideggerian) which emphasize the priority of learning actions and rules over the cognitive concern which is characteristic of transcendental phenomenological theories. The concern is with praxis rather than theory in the attempt to avoid the reflexive paradoxes. Language is assumed to be its own referent and so sociology is simply an attempt to understand what is trying to be communicated through language. Thus, the normative aspect of sociology is to help

mediate the expression of moral freedom which enhances dialogue. As already mentioned, Heidegger (1977) even criticises the centrality given to worldviews. Worldviews are seen as abstractions and are not the source of activity. As an abstraction referring to 'assumptions' about learned activity they may become a significant feature of dialogue, but it is only when they are thus expressed that they formally have a role. Any other theorising is itself metaphysical speculation which diverts attention from the role of sociology to nurture individuation.

Heidegger, in contrast to Wittgenstein, did however reflect upon the evolution of dialogue which occurs. He posits a shift from discourse which focused on metaphysical views, to postmodern concern criticising rationalism which has given rise to the metaphysics held since Plato.

Heidegger is also helpful when considering that as well as the cultural meditation found in discourse of which sociology's meditations are a part, change is also found in individual meditation as the expression of the ontological relation. In fact individual meditation informs cultural meditation. Cultural meditation is an expression of how the community of individuals is responding to second order feedback.

Some language game theorists have been realist in the attempt to claim that the changes in dialogue are historically based. Language games are taken to be real mechanisms that act causally to direct human activity (e.g. Outhwaite 1987 and Woodiwiss 1990). In the rejection of social constructionism by these views they adopt a view akin to rationalism that ideas held in language exist independently, even if they are not necessarily seen to be tied to an external reality. Social constructionism in contrast will only accept that signs somehow stimulate ideas in human minds without claiming that the ideas are the same. The postmodern empiricism developed here argues that if some real collectivity occurs it is not in the ideas but rather in signs themselves, with another actor which is an immortal god making a human community, which mediates through the creative making of signs.

#### **4.1.2.3.5 Critical social theory.**

Critical social theory uses both causal and organismic metaphors though in different ways to functionalist theories. It is a critical development of phenomenological theories. The critical development is in response to interpretation using a causal metaphor describing power which is perceived as occurring as symbolic violence in the relations between the expression of worldviews. Power structures are perceived in a phenomenological way. Three forms of power are perceived: dictatorship, masked agency and structural

relationships inherent in dominant worldviews.

The typology is similar to Galbraith's (1983). The 'condign' power of Galbraith is equivalent to dictatorship, as well as the 'trust in distrust' Luhmann described. Masked agency is equivalent to the 'compensatory' and 'conditioned' power of Galbraith, as well as the patronising 'trust in trust' described by Luhmann. To perceive masked agency requires the use of a 'hermeneutic of suspicion' (Mohanty 1984) to deconstruct ideology so as to not be fooled into 'trust in trust'. Structural power is not covered by Galbraith and is ideology in its neutral sense where the power is expressed (and received often) unknowingly. It is expression of systemic neurosis that is not fully reflexively recognized by the people involved. Individuation does not occur fully among everyone and so the people involved are always to an extent unaware of the situation. A concept that is related to it is that of 'false consciousness' which complements the unknowing expression of power by 'oppressors'. It is conceived of as a view held by those oppressed that they are not oppressed because they have not become individuated to the extent to be able to perceive the systemic neurosis. The ability to recognize that 'false consciousness' occurs as well as oppression, even when the oppressed are not fully aware of it, is what critical social theories attempt to carry out with phenomenological analysis.

One way they attempt to do so is by using empirical techniques to statistically test null hypotheses that causal trends or relations of power do not occur. The purpose for the use of the causal metaphor is to try to overcome 'false consciousness'; to unmask hidden agency, and to overcome the ignorance of those expressing systemic neurosis. This leaves unaddressed however what is the most effective way to do so.

There is a variation on this basic approach which attempts to answer the unaddressed question; standpoint epistemology (e.g. Rixecker 1994). It takes an explicit phenomenological approach, claiming that different individuals have different perspectives. It is Nietzschean except in that the systemic reflexivity or eternal recurrence and hence individuation is not recognized. Instead unreflexive relativism is held, with the assumption that an objective reality is able to be alluded to, in keeping with transcendental phenomenology. The method is used to try to overcome structural power as well as other types through the attempt to widen the scope of discourse to include the appropriate moral community in decision-making. The approach is inadequate on at least three grounds. Firstly because 'false consciousness' is not recognized as significant. Those unknowingly having power exercised over them can not be expected a priori to engage in dialogue to challenge decisions being made that are oppressive. Secondly, for discourse to occur requires some commonality of worldview requiring reflexive awareness of actions. This

cannot be assured. If it cannot, even if the possibility for discourse to be widened occurs, it may not be able to happen to affect any decisions as neither communication nor learning may occur. The failure to see this flaw is likely to be due to the holding of rationalist epistemology. The founder of the approach, Habermas (1970a and 1970b) was explicitly rationalist. Thirdly, decisions achieved through full participation and effective discourse are still interpreted as actions of power. The appropriateness of power per se is not addressed. It can be expected however that, to the extent a particular decision-making situation can be aided by more information pertaining to an issue being discussed, implementing standpoint epistemology may help.

The third inadequacy can be addressed to an extent through deconstruction of power by the genealogical method. An example is Foucault who took a hierarchical approach like Whitehead and so considered how the various levels of systems have been socially constructed (see McGee 1994). He used an organismic metaphor to carry out *diagnoses* of the situation. Part of what he diagnosed was power, describing how it arises as elite control operationalized through elite knowledge; for example, the abuse of professionalism discussed in Chapter 3. Power is seen here to arise due to interpretation with a causal metaphor that creates a particular language game of control. It means that standpoint epistemology can be expected to create relations of control. The mistake is to view power as an essence behind all relations. What has to be avoided are unreflexive analyses that interpret power through use of a causal metaphor where it has not actually arisen within the language. To do so is to create a self-fulfilling prophecy which creates power relations. Wilden (1980) termed it a type of systemic paranoia. Mohanty (1984) links it to an over-zealous application of the hermeneutic of suspicion.

#### **4.1.2.4 The use of sociological traditions.**

The different sociological traditions have all been shown to have some application in reconstructive development of language games. Within them there have been found to be several different types of expression used in language games which can serve different purposes. What the main concepts are that have been elucidated as useful for integration with the other aspects of a systems approach to environmental management are highlighted below and serve as the basis for development of an appropriate systems methodology in Section 4.2.

##### **4.1.2.4.1 Interbeing**

As previously mentioned, the beings in interbeing are mortals, gods and the Sacred.

Language as human community forms the most obvious being that is interbeing with human beings. It can only be discovered however to the extent that language lets itself be revealed however. It can be claimed coherently that it is only in the postmodern use of language that language is allowing itself as a god to be discovered. This is the Heideggerian interpretation. Also, relating with other mortals is only possible in language and so it can also only occur to the extent that the language god of community facilitates it. The silencing of non-human Nature by how modern language which objectifies Nature is well attested to (Manes 1992). The Sacred transcends language and so has control over language and so language reveals grace as any immortal god does. This is well attested to in some Analytical Psychology (e.g. Neumann 1959 and Fromm 1942), and is what religions refer to when mentioning the 'word of God' or 'divine revelation' (Lane 1981).

Relations in interbeing are able to be described in terms of the organismic metaphor, which enables them to make conclusions able to be used for social consequences. There are many models which do this, and many poignant conclusions. Especially significant is how ethics is able to be incorporated into social organization. Revelation of grace by language has a purpose that operates at least at two levels: to nurture individual growth and sense of meaning - awareness of the Sacred at all levels - and socio-cultural adaptability of language games for social and ecological integration so that individual growth is maintained (see Chapter 3).

#### **4.1.2.4.2 Types of expression.**

The types of expression made are the ways of thinking of human beings. Two main types occur: language without knowledge, and language with knowledge. Language without knowledge is language which facilitates relationships without alluding to an objective reality. This is language which is the expression of the initial distinctions which give rise to system and worlds that have no basis except that of grace in wilderness (see Chapter 3). Building upon these initial distinctions is the development of worlds through the interactions of the signs which are usually socially constructed. This language contains knowledge, but it can always be changed. Therefore language to be alive (hence the community to be alive) has always got to have a deconstructive element which takes language back to its initial state without knowledge facilitating wildness and the ethical relation, while also reconstructing collective worlds through social construction involving individual creativity. An adaptive culture is one that is freely deconstructing and reconstructing so as to stay wild and hence civilized. The whole point of postmodernism is to free up the process and not to get stuck into any particular socially constructed world

that it is dysfunctional.

#### **4.1.2.4.2.1 Reconstruction**

Logic according to rules gives rise to discourse elaborating on basic premises or distinctions. From these fundamental distinctions logic develops worlds into more and more sophisticated realms as different rationalities (Lemons 1989). Not only are the basic premises or distinctions tautological, the rules for logic are also undefined and so rationality is itself open to contextual development (see Chapter 5). As developed worlds emerge knowledge can become accepted as absolute truth which essentializes nature and so the language game may become dysfunctional because of refusal to be adaptive. The consequence can be disruptive deconstruction when dysfunctionality becomes obvious. This is why the innermost sphere (see Figure 4.5) is both creative and graceful and is yet also where conflict arises. If creativity is not expressed so as to adapt language, conflict will deconstruct it eventually. The second-order feedback occurs either gently or violently (Wilden 1980, Neumann 1959 and Fromm 1942). The dynamic is generally termed co-evolution (Noorgard 1988).

If logic can be used in a way which enables critical and creative expression it can create a rationality which produces evolution rather than revolution (see chapter 5). The logic requires to be an expression of the hermeneutic circle so as to incorporate all feedback as it emerges. To maintain openness to all possible feedback a 'hermeneutic of respect' is appropriate (Mohanty 1984). It has to complement and be prior to the application of a hermeneutic of suspicion. This opens up interpretation to respect all intrinsic values through taking all discourse on its own terms through the discovery of the ethical relation. There is openness to the wisdom of grace from all sources (see Chapter 3). In doing this the hermeneutic circle synthesizes language without knowledge with language with knowledge. Intuition integrating feedback is allowed to inform the creation of new premises for logic. The processes in the hermeneutic circle are not only cognitive however. Just as the context for thinking involves becoming aware of learned activities so as to know one's 'worldview', learning is just as much a process of changing behaviour and taking responsibility for what one does. Openness to the Sacred and perception of a vision is also to maintain personal relationships of caring for all in the process of sacrifice so that others live (see Chapter 3). Thus personal virtues are the touchstone for creating good rationality, as concluded by Naudascher (1983), Schumacher (1973) and Weare (1991) (see Chapter 3).

#### **4.1.2.4.3 Dynamics of the reflexive spheres.**

The dynamics of the reflexive spheres have been described in several ways by different analyses framing the situation differently. Four examples are given from Western traditions. They have all been mentioned already in the review of sociological traditions. Clarification of how they reveal how the reflexive spheres operate is helpful for developing a methodology which is based on the reflexive spheres over-metaphor. They all frame the situation in terms of both linear time and otherwise. Note that the reflexive spheres imagery does not assume any particular conception of time. It has been developed so that it can be used to transcend different models which have been produced while giving a root metaphor with which to base the postmodern view developed here.

The four traditions are:

1. Systems theory.
2. Decision theory.
3. Analytical psychology.
4. Marxist development psychology.

##### **4.1.2.4.3.1 Systems theory.**

Wilden (1980) makes a very comprehensive exposition of how to use the organismic metaphor to consider open or living hierarchical systems. He argues that they are patterned diachronically and synchronically which gives perspectives of both linear time and eternal timeless relationships of change. Wilden juxtapositions the two so as to describe what is successful co-evolution. Adaptation is considered to be response to feedback. Two types of feedback are recognised as leading to two types of behaviour which can be understood in terms of synchronic analysis. Adaptation in response to first-order feedback is behaviour that enhances the realm of the sub-system in question. In diachronic terms it enhances survival. For example population or wealth may increase. It occurs when requiring to establish a niche or role. It is a positive feedback. However if it is pursued without concern for synchronic integration it will result in counter-adaptive adaptation because it will destroy its environment. Thus second-order feedback emerges which limits first-order feedback or changes it. It is negative feedback, also called renormalisation (Wilden 1980). Thus diachronically speaking adaptation has a norm which is maintained by negative feedback to maintain a holistic approach. In social terms it can be considered cooperation. It is the expression of social construction through moral freedom. Long-term survival or sustainability and adaptation requires it. In changing first-order feedback, second-order feedback is changing the structure of systems. Thus it



is what directs morphogenesis. Second-order feedback is operationalized through people being creative to express wisdom through openness to grace or wildness experienced as vision and the ethical relation of care or love. Because the norm that directs through second-order feedback is transcendent of language, norms cannot be defined. What can be defined however is deviance from the norm, or in other words monitoring.

Wilden's analysis also enables an analysis of when power emerges so as to clarify when the use of a causal metaphor is appropriate. He argues that it occurs when second-order feedback is denied. In denial of integration, increased control over the environment is sought in continued response to unmodified first-order feedback. This increase in control is manifest as power. Wilden also links this to 'madness'- the refusal to acknowledge the environment: to be out of touch with reality. An extreme case he points to is paranoia in the attempt to insist on the use of the causal metaphor to consider all interactions. It destroys all possibility of integration and expression of moral freedom. As already mentioned, critical social theory can suffer from this.

#### **4.1.2.4.3.2 Decision theory.**

Argyris' (1982 and 1988) theory of 2-loop processes (see Figure 4.3) is akin to Wilden's. Argyris however neither uses an organismic metaphor nor considers cognitive aspects. He insists that it is a theory that is purely descriptive and fits within the cybernetic approach of explicitly defined goals. This may be interpreted as a weaker version of Wilden's theory or only a description of nuances around first-order feedback. It is easier to integrate it within other system theories if the latter interpretation is made because Argyris defines goals explicitly.

#### **4.1.2.4.3.3 Analytical psychology.**

Jung and his followers (e.g. Neumann 1959 and Vander Post 1986) explicitly concern themselves with the cognitive dimension. Integrating their approach into systems has however still been termed postmodern because it questions the Cartesian notion of self and objective reality (Ivanov 1991). As with Wilden they juxtaposition the diachronic and synchronic, but without using an organismic metaphor. They explicitly use mythic metaphors. The synchronic for them is seen to occur in what they have termed the collective unconscious which is the 'pool' of consciousness that all 'tap' from. It is the content of the collective unconscious which is seen to give rise to second order feedback. It is recognized to operate non-causally and Jung (1960) uses imagery from archaic traditions to describe it, though he also termed it synchronicity.

The feedback is said to be experienced as dreams or visions. Van der Post relates how for the Southern African Bushmen dreams revealing socially and ecological norms are *big dreams* and the dreamer is then pained to reconstruct the communities' language games. This indicates that human creativity can have a 'prophetic' impact revealing 'God's word' as feedback from the transcendent. Such prophets or big-dreamers are often artists, who perform the role of seers in traditional cultures (Neumann 1959 and Campbell 1972). As already mentioned, Jungian theory integrated these concepts into the concept of individuation whereby a person integrates second-order feedback so as to be integrated socially and ecologically, and is equivalent to Heidegger's concept of ontological growth leading to overcoming alienation.

#### **4.1.2.4.3.4 Marxist developmental psychology.**

Fromm (1942) developed a theory akin to Jungian theory but which does not use the concepts of the collective unconscious nor individuation. Rather the concept of neurosis is used to refer to fixation within particular worldviews that block psychological development; and the concept psychosis refers to the overwhelming possession by psychological processes that are instrumental for growth.

Neurosis, in light of Wilden's theory, refers to the conditions which give rise to the attempt at power to try to control because the telos of growth directed by second-order feedback has been suppressed or denied. Fromm used the image of rationalism as 'concrete' causing neurosis because creativity is suppressed. It is a common view still expressed (e.g. McGinnis 1994). Fromm argued that eventually the suppression builds up 'pressure' in the psyche to topple the 'concrete tower' -i.e. to deconstruct through revolution. He pointed out that it is more often than not artists who topple the concrete tower. He adds that this can be detrimental to the individual artist because of the trauma that it brings through the conflict with those neurotically expressing power to control others. It is such trauma which can lead to psychosis. Authentic reconstruction is perceived as impossible in the social environment when psychosis occurs.

Merton (1971) develops this further and defines *social integration* as a type of neurosis (playing the game unreflexively) and *final integration* which involves a person being open to vision to direct their creative and responsible social and ecological integration. Merton points out that final integration is rare and those engaged in seeking it risk being condemned as mad just as religion tells about what happens to 'prophets'. Campbell (1972) adds that the process of people becoming seers in traditional cultures is akin to what is labelled schizophrenia in Western psychology. Merton concluded that

people who are getting close to being conveyers of wisdom in modern societies are liable to be given shock treatment!

Individuation may be the ideal, as Jungian views tell, and a necessary component for wise social reconstruction of the use of technology, but it can not be expected to be an easy thing for an engineer to attempt to do. This research bears testament to that.

#### **4.1.2.4.4 Social construction and reflexivity.**

The four theories all lead to insight into the dynamics of the reflexive spheres. An aspect of a comprehensive treatment that is missing from those four traditions however, is how authority and teaching arise. Neo-marxist accounts assuming that all teaching is expression of power as 'symbolic violence' for the sake of 'cultural reproduction' (e.g. Bourdieu and Passeron 1990) are incoherent because a functionalist metaphor enabling usefulness is not used. Only causal metaphors are used. Such analyses are close to a state of paranoia as Wilden (1980) points out. A coherent alternative is to consider the relationship between a mortal being and language as interbeing. A person can then have ethical authority to teach so as to construct the world for another through the facilitation of language if it nurtures the ontological growth of others. Awareness of, and communication about false consciousness may be an expression of this in certain situations. No power is required as the language game is in accord with the telos of growth of both involved. The relationship is an expression of the ethical relation. Therefore a person can outgrow a teacher and start to teach others as they ontologically grow through the nurturing of the teacher. This gives a basis for understanding how an ethic of non-power could work and how a model for professionals who have integrity, but who are not elite, could work. There are two aspects to this which are especially important: the appropriate use of power and the role of sacrifice.

Appropriate use of power has to be monitored as developed earlier because consequences are never certain. Technological development using a causal metaphor to transform/manipulate to redistribute utility has to be sought to be integrated within the wider hierarchical web of interbeing interactions. This can only be carried out if the necessary feedbacks requiring monitoring are appreciated, which requires a degree of individuation and 'big dreaming'. However it can be aided immensely by cooperative understanding sought through the attempt to express moral freedom (see Chapter 3).

Sacrifice takes individuation a step further than the achieving of social and ecological integration to be functional collectives. It involves facing the systemic reflexivity that occurs that makes mortals mortal; i.e. that life and death co-exist in

ecology. The telos of growth that ethical authority nurtures leads to death. Dying occurs with growing and is part of the process of becoming an authority. Powerless authority is a sacrifice of oneself. It is given unconditionally in the ethical relation of love and leads to increasing learning and relating with the sacred transcending language games as individuation proceeds, ending in final integration or self-actualization (see Table 2). It is the fulfilment of one's ontological growth and telos. It occurs in all ecological and social processes. Many traditional cultures recognize this and interpret ecological processes involving death as a life being given by those eaten to others, rather than as a failure to compete (e.g. Wenzel 1991). Bratton (1992) develops one aspect of this view by pointing out how sacrifice (she uses the term *agape* love) is required to correct injustice.

Thus the processes involved in social construction are on two levels: the individual and the collective (see Chapter 8). In terms of individual rights it is only the level of the individual which has meaning in itself. The collective only has meaning to nurture individual meaning. Individual meaning defines what is meaningful in collective processes. This is another way of saying that the systemic whole that is an interbeing of life is life-nurturing. The gods and the Sacred nurture life - life is meaningful. It is poignant to note that the abuses of the use of the organismic metaphor have inverted the definition of meaning in terms of the levels and in the process legitimize destruction of life (Fromm 1942 and Ferre 1989). In these cases the social collective is given intrinsic value.

The hierarchical functionalist theory of social construction (radical constructivism) by incorporating the two levels can usefully be compared here with the theory that Checkland uses because Checkland's work serves as a starting point for methodological development (see Section 4.2). Checkland's view comes from Churchman (see Checkland 1988a). Churchman defines a dialectic process of co-evolution between idealism and realism. *Ideals* are goals held within social systems that when implemented are constrained by the *real* world. Constraints give rise to new ideals. It is akin to Whitehead's process philosophy and so describes the language game aspect of the process. The ideals/constraints dialectic is an expression of feedbacks, and the theory is consistent with radical constructivism in a systems framework, but it does not define the distinction between the types of feedback, nor the existence of interbeing involving language and reflexivity through ontological growth. The two levels are not distinguished.

#### **4.1.2.4.5 Sustainable development and reflexivity.**

The concept of sustainability can be analyzed usefully in terms of the reflexive

spheres metaphor and corresponding theory. The World Conservation Union (IUCN 1995) argues that sustainability must be considered in terms of development. Or in other words, the social dimension must be appreciated. This can be taken a step further in making the point that sustainability is a concept being used socially and so its use in language games requires it to be addressed if any analysis is to be reflexively coherent.

The first thing to face is that sustainability is both normative and descriptive; and explicitly draws on naturalism. Therefore careful avoidance of the Is-Ought fallacy is required (see Chapter 3). Vickers (1968), much lauded by Checkland and Casar (1986), uses the term *appreciation* to describe such syntheses of values and facts. Mythologies expressing visions so as to define fundamental premises for reconstructive rationality are examples already discussed. The challenge is to reconstruct coherent appreciations.

The task is to consider how sustainability can be formulated so that the descriptive and normative aspects can be rationally developed according to some premises. Shiva (1993) links sustainability to bio-diversity and to the two levels of the individual and the collective, thus the ethical theory developed in Chapter 3 and the systems approach developed in this chapter can be used to structure it. Grumbie (1994) adds the ecological dimension, and the need for analysis and formulation that promotes ecological integration - humans as populations in regionally specific ecosystems. Therefore language games' fundamental appreciation is akin to a postmodern notion of bio-regional narratives (Cheney 1989 and Snyder 1990). Grumbie contrasts these approaches with biospheric approaches which he considers to be inadequate.

Grumbie's critique of a biospheric basis for sustainability is illuminating of how the reflexive spheres over-metaphor can be used to help formulate an adequate appreciation for sustainability. Biospheric approaches concern themselves with resources and the need to not deplete them. Sustainability is conceived as the ability to sustain resource use. The insistence on the use of renewable resources is logically concluded. Grumbie argues however that this is not sufficient. It is necessary but by itself will not fulfil the values associated with the concept of sustainability. Concern only for resources does not necessarily respect all intrinsic values and so in open systems where the intrinsic values in the environment need to also be considered sustainability may not be able to be achieved through a biospheric approach. In system terms it decreases its flexibility to the extent that it is unable to adapt to environmental changes that occur (which can even be of its own making). The biospheric approach uses a thermodynamic metaphor of inputs and outputs to attempt to define all feedbacks without consideration of the two types. As developed already, this is due to a flawed philosophy of science as well as inadequate

ability to consider the mathematics of uncertainty and imprecision for goal achievement. However it has been the utopian view of systems for engineers associated with cybernetics (see Chapter 3). The incoherence comes from not facing how system analyses are social constructions and that they will only be maintained as long as they work as language games to produce individual and collective meaning (including sustainability). They are inadequate to achieve the latter, and actually are the cause of alienation destroying the meaning for individuals. The system model developed would predict revolution if such models were attempted to be implemented. Such revolution could be interpreted as the means by which the world heals itself from the 'cancer' of technology (Ellul 1980 and Lovelock 1987).

What is required for formulation of an ecosystemic approach and adequate appreciation for sustainability is to address the need to produce meaning individually and collectively. The link between sustainability and adaptability illustrates this. Sustainability implies long term adaptability. Ironically this means however choosing not to try to sustain a trajectory. The development aspect of sustainability can only be interpreted as flexibility to evolve rather than to maintain a state or style of 'development'. Because of this it may be better to drop the use of the term sustainability and to simply use the term adaptability. Making this step produces a coherent approach because long term adaptability requires to have as the norm maximization of flexibility and hence the aim to seek to increase bio-diversity and social justice through functional integration. This also addresses the need for individual meaning as sacrifice is the way to achieve this functional integration.

To operationalize such an appreciation requires to replace utopian visions giving explicit ideals and goals in a linear time frame (e.e. Argyris' approach) with that of visions of the eternal 'cosmic dance' of grace and wildness which only allows contingent social construction of goals. Renormalization away from discovered distortion/perversion/degradation is what has to be operationalized without being able to explicitly define what should be done. It is only ever different non-sustainable activities that are defined rather than sustainability; with the only true end being existentially given for individuals in interbeing transcending biological death. It has to be conceived as eschatological rather than utopian. This is aided by first-order feedback to the extent that technological innovation may be necessary to establish a niche socially and ecologically, but second order feedback must also be actively sought so as to guide how to effectively love.

On the collective level a distinction made by Vickers between the functional and

metabolic is helpful. The functional refers to the need for integration at the various levels of open systems. The metabolic refers to the need for the exchange of utilities between all beings functionally integrated as systems. Awareness of this distinction enables economic theory to be integrated within methodology (see Chapter 8). The ecological principle of death giving life can be described by the concept of reciprocity referring to utility exchange in terms of fulfilling metabolic processes. The exchanges may be very sophisticated and properly be called an economic system (see Chapter 8). That reciprocity is a necessity for integrative processes via the metabolic means that it has to be distinguished from symmetry which Wilden (1980) describes as a paranoia because the causal metaphor is used exclusively to describe all exchanges in terms of autonomous objects.

The contrast of symmetry and reciprocity gives further insight into the inadequacy of the biospheric approach. The use of a systems analysis to control resource use involves control of society or the exertion of power to maintain a balance/equilibrium of exchanges according to the principle of symmetry. Thus, even in its emergence it is inherently flawed and can be expected to be counter-adaptive. It has links with economic theories which define essential human nature involving competition according to principles of symmetry (see Chapters 3 and 8).

#### **4.1.2.4.6 Maori social organization.**

Because of explicit openness to the sacred (see Chapter 3) it can be expected that the mythology of traditional Maori would premise a rationality and language game that does take into account second-order feedback. This appears to be the case. It also appears to explicitly recognize and implement an ethic of non-power. Thus some equivalent to the social construction theory of authority developed above is integrated into social organization. The way this is done is straightforward and should give direction for reconstruction of Western society.

A concept of *mana* is held and refers to a state of having authority given by the gods which is equivalent to the notion of authority developed above. It is distinct from power because it is only ever obtained by it being given by the higher order levels which are sought to be integrated with. It cannot be taken to mean control or manipulation. Being such a central image, Patterson (1992) argues that the seeking of *mana* is the most important principle in Maori social organization. Matunga (1995) has pointed out however that it cannot be achieved if sought for its own sake. It is a norm that, like growth giving authority, requires reflexive openness to others in direct contradiction to

self-seeking. It is an expression of the ethical relation. Mana continues to be bestowed if integration, renormalization and wise teaching is carried out. Mana grows as a person fulfils their telos of ontological growth. Second-order feedback is recognized as needing to be individuated.

The second step is to structure society so that those with mana are the leaders. Therefore society as a structure and language game is integrating second order feedback to ensure the cultural tradition (language game) adapts and so stays alive. The mythology opening up to the Sacred is developed rationally to provide rules. This is carried out by adding and interpreting proverbs (Patterson 1992 and 1994). As mentioned in Chapter 3, Patterson (1992) also points out that there is no attempt to essentialize an ethical system as a metaphysical construct. Metaphor is used explicitly and juxtapositioned freely so as to reveal the opening to the undefinable/Sacred. The sea of the collective unconscious and language without knowledge has ships of proverbs with limited and contingent and specifically relevant information floating upon it.

#### **4.1.3 Conclusion**

The challenge to incorporate second-order feedback by the engineering profession so that wisdom is expressed creatively with an ethic of non-power, enables the incorporation of the appropriate use of technological development. The rest of this chapter is an attempt to review and reconstruct appropriate systems methodology that enables appropriate technological development to be ascertained in any particular situation in light of the above discussions.

While attempting to do this, it is also recognized that to do so has the grave dangers mentioned by Fromm (1942) and Merton (1971). The attempt to discover and implement such a creative transformation involves sacrifice. It has to involve a labour of love carried out in hope. That is how this research has been carried out.

## **4.2 DEVELOPMENTS IN SYSTEMS RESEARCH**

There have been four stages in the development of systems research to date. The four stages show an increasing awareness of ethical concern.

- (i) 'Hard' systems analysis.
- (ii) 'Soft' systems methodology (SSM).
- (iii) Critical systems theory (CST).
- (iv) Postmodern systems theory.



#### 4.2.1 Hard systems analysis (HSA).

Jones (1982) (see Section 4.1) defined a system which was an attempt to formalize the boundaries and hence the context of system analyses through use of a causal metaphor. This is in contrast to what can be called the holistic view which holds that systems thinking requires to ever extend the context being considered (e.g. Churchman 1968 and 1974). The holistic view argues for the need for never-ending questioning and adapting of one's world view. Jones argues in contrast that there are appropriate limits to what should be considered a system. To use Naess' et al. (1984) terminology, Jones' view can be termed 'shallow' and the holistic view 'deep' (see Chapter 3). Jones assumes that the purpose of defining a system is to enable control to be exerted. Jones' definition of a system is appropriate for what has above been called engineered systems and is an example of the method Checkland (1981) calls 'hard systems analysis' (HSA). They are systems where goals are defined. Hard system analyses also commonly use stochastic knowledge with a random generator metaphor.

In hard systems analysis only the analyst is seen as perceiving meaning because systemic reflexivity is not appreciated. A metaphysical world of objectivity is used to base the system on. Hence intrinsic valuing is not carried out by the analyst except in relation to themselves and their client. HSA is not reflexive. For this to be appropriate the defined goal has to be evaluated independently of the hard system analysis. The hard system analysis has to be considered in the context of some other type of analysis (Miles 1988). A hard system analysis is an appropriate sub-analysis when the context is acceptably bounded and only involves causal and stochastic relationships. Checkland (1981) has defined hard systems analysis as a special case of a more general methodology he termed Soft Systems methodology (SSM) which enables this to be conceptualized (see later section).

As mentioned in Section 4.1, Jones (1982) recognises a limitation in his definition but does not ask further (deeper) questions. The deeper questions need to be asked however. As also already mentioned, Emery (1981) along with Jones, has recognised that even when causal relationships are what are defined, the system that exists is not independent of the type of environment. Emery argues that a 'turbulent environment' requires an adaptive system. If the environment changes to a large extent then the system has to also if it is to continue to exist. The control mechanism of the system cannot be merely determined by the causal relationships within the system. The attempt to control using causal relationships does not give the stability required for the continuing existence of a system entity. Second-order feedback to change the structure is required to be

sought. The integrative tendency if the moral community is extended has to be extended and to be made explicit.

For example, the use of retaining walls to hold back the base flow in a river, so as to protect a camping ground, will require structural change in the camping ground system when very large flows (by definition floods) come down the river. Some higher level organisation is required so that the camping ground system can adapt structurally to the large change in the environment. Emery argues that approaches other than exertion of power, and hence relationships other than causal ones, have to be sought to fulfil the purpose. Emery argues for the holding of ideals which seek to maintain relationships within the system (see Section 4.1). In the example above, the system has to be adaptive, not so as to control the river, but to maintain the integrity of the camping ground. For example the camping ground may have unique river scenery, and so a low impact on the environment is necessary to maintain the relationships that make the camping ground what it is. So some warning system is appropriate, so that when floods occur the camping ground structurally changes and moves temporarily to higher ground.

#### **4.2.1.1 Control**

The term control is used in two ways. Control in the sense of causal relationships enacted through the use of power, for example by building larger stopbanks; and control in the sense of using information which regulates through feedback, vastly amplifying power, and directing the main power being operated in the system, for example a warning system which operationalizes the complete evacuation of a camping ground which is beside a river. Emery is suggesting that information control has to direct the change of the structure of the causal relationship network present. Or in other words it has to regulate it. Cybernetics is an example of control in the second sense which involves regulating a system, e.g. a warning system which directs the piling of sand bags on top of a stop bank. Hard systems analyses can carry out cybernetic analyses. As already mentioned, Steir (1991) points out however that reflexivity for incorporation of second-order feedback requires a cybernetics of cybernetics. It is what Soft Systems Methodology (see Section 4.2.2) attempts to do.

Jones' (1982) system definition by contrast is only appropriate for a stable environment, i.e. in a state of homeostasis or equilibrium, for example if only base flow in the river system mentioned above occurs. It can be created and is appropriate for example in a river that is highly regulated. It is significant that the condition of equilibrium is assumed by neo-classical economic theory (see Chapter 8). For example,

the use of taxes on dwellers by rivers for flood-protection works (to regulate streamflow) can be set at a level to ensure that protection from the river will be carried out so that the net wealth produced on the floodplain is maximised. The ability to use techniques of control fail if some such equilibrium cannot be maintained. For example, if no amount of attempted control of the river and taxes on the floodplain dwellers allow for sustained production for a market the system will collapse. Or alternatively, if external trade changes make the production being carried out uneconomic, and/or if larger than designed-for floods occur which require capital reinvestment which is too great a financial burden and so become a constraint because of the interest rates at the time, collapse occurs. This example is further addressed in Chapter 8. First-order feedback of cybernetic control to control when, where and what production is appropriate is required. HSA involving homeostasis is required to be nested within cybernetic analyses, which in turn require to be within functionally defined systems.

#### **4.2.2 Soft systems methodology (SSM).**

Checkland developed SSM to handle situations that do not have well-defined goals, as hard systems do. They consider themselves along with the context/environment from which hard systems analysis' goals are defined. This means that SSM considers systems where norms and second-order feedback can play a part to produce structural change. SSM can help create 'language games' with rules that can be receptive to the constraints given by moral intuition and hence provide negative feedback necessary to guide the evolution of human society into responsible integration with the various levels of the open system hierarchy.

Checkland (1981) explains that he uses the term 'methodology' rather than 'analysis' because SSM contains philosophical considerations. This is a recovery of the aspect of systems research that cybernetics lost, according to Bertalanfy (1969). Bertalanfy lamented that cybernetics as an offshoot of GST lost the philosophical understanding and reflexive questioning which was a part of GST. 'Depth' has had to be regained. The attempt to do this is a way to interpret Checkland's research agenda.

##### **4.2.2.1 Norms and SSM.**

Checkland (1981) wrote approvingly of the use of a language game approach but used the term 'speech acts'. Mingers (1984) argued against language game theories however because they may conflate action and meaning - as if intent has no place - but misses the point that people can be reflexively transcendent (individuated) from the

socialization (social integration) of conforming to the cultural canon of a language game. It is just not the norm, that is all. It is 'normal' to be 'shallow' and not 'deep'.

The norm of human behaviour is the socialization into the cultural canon, thinking and acting out language games unreflectively. People do not reflect on intentions but rather learn to 'play the game' because they have been trained to do so, and because it brings the rewards of social compliance. Compliance to how one is wanted to be used as a resource, keeps one maintained as a useful resource. Argyris (1982 and 1988) describes how this occurs even when people espouse significantly different views to those enshrined in the cultural canon, and even criticise it. When the crunch comes for the need to act, rather than to only talk, people revert back into their 'theories-in-use' based in the cultural canon. This hypocritical behaviour is rationalized commonly in terms of having to return to the 'real world' (sic). The enigmatic phrase 'returning to the real world' crops up especially when economic matters are involved. According to the social constructionist approach developed above the statement has some truth in it, as the language games that are felt to have to be conformed to are in fact strong social forces exerted as power when insecurity occurs. However it is also clear that such behaviour also shows lack of ethical integrity because reflexivity opening to the sacred is suppressed and so ontological growth is also. Systemic neurosis is not overcome through individuation. The point is that the social forces of power can be changed by not submitting to play them.

Argyris argues that this lack of ethical integrity is due to the desire to protect oneself from social exclusion and the loss of privileges. However socially the result is the breakdown of communication and counter-productive results: the perpetuation of the problem. Second-order feedback is denied and so growth is suppressed. There is not expression of authentic authority and so learning is not achieved. Inappropriate use of hard systems analysis can be an expression of this if the use of the causal metaphor is not placed in context. As developed in Chapter 3, this is the norm in modern technocratic society.

Checkland attempts in SSM to seek ways to improve situations to stop the mere perpetuation of the problem the socialisation into modern technocratic culture has brought. He uses the metaphor of a learning system learning about a situation that has to be considered. No specific goal and final solution is expected to be found. He uses an organismic metaphor to frame the learning process so that it can be interpreted as adaptation in co-evolution. Checkland (1988a) acknowledges a debt to Churchman for introducing him to the principles of adaptive learning systems. Churchman (1968) criticizes hard systems analyses because he considers a system needs continual re-

evaluation. Interestingly, Churchman also assumes that there is a potential systemic reality waiting to be discovered - systemic reality (eternal recurrence) to be individuated - but the human mind is unable to gain an adequate understanding of the whole so as to be able to perceive it. He did not perceive the ontological relation as open-ended with the possibility of final integration. However Churchman did pose the problem as an ethical one. He proposed that to use systems analyses for good purpose means that an understanding of the consequences of the implementation of the analysis has to be gained; i.e. he proposes the use of consequentialist theory. However, as he himself then proceeds to articulate, when this is attempted the impossibility of the endeavour becomes clear with the impossibility of defining norms.

Churchman posed the problem in terms of causal chains and their interactions. Because of the never-ending chain effect, and the interactions, it becomes impossible to determine all of the consequences, and therefore it is never possible to adequately make a decision according to a consequentialist ethical criterion. An awareness of the whole of the situation is not possible. Therefore norms cannot be defined. As already mentioned, Busch (1989) goes so far as to claim that systems planning has an inevitable irony in giving unexpected results.

Churchman (1968) suggests the response of humour to cope with the irony and joke, as well as the perpetual reformulating of the system analysis so as to try to improve it. This view of Churchman is in contrast to that of Jones (1982) who construes the problem as being the other way around: redundant system formation of causal chains which are significant. Churchman is reluctant to define any causal chains as insignificant. Ironically these are exactly the situations which require ethical reflection, as adaptation is being sought so as to improve the situation. Checkland (1988a) took a middle road between the views of Churchman and Jones, and argued against what he calls 'systems promiscuity', where the issue of significance is not faced, and arbitrary system formulations given. Checkland's view can be interpreted as requiring a concern for the environment, i.e the context for the definition of a hard systems analysis in the attempt to discover significant systems where organismic metaphors enabling purpose to be appropriately defined can be made. This allows norms to be defined at a meta-level. As developed in Section 4.1, at the lower level the meta-norms can only be implemented by monitoring for deviation from the undefinable norm. This approach has been begun to be systematised by Checkland in SSM and is continued in its development by this research and applied for environmental management and specifically floodplain management in subsequent Chapters.

#### 4.2.2.1.1 Relationships and goals in social structure.

The other systems researcher to whom Checkland acknowledges a debt, Vickers, extends the criticism Churchman made of 'hard' systems analysis, by arguing that human behaviour is not only concerned with goal-seeking. Vickers (1968) argues that relationships exist which cannot be reduced to goal-seeking. Checkland uses this to base his development of the notion of the community dimension to situations requiring SSM because situations are not able to be defined only as HASs. Therefore 'managing relationships' needs to be carried out as well as defining and fulfilling goals and even norms. Vickers argues that these two aspects are always both present. For Vickers, relationships are defined by what Wilden (1980) calls the synchronic aspects. They are defined according to an organismic metaphor, as already outlined. Therefore once again what is considered to be necessary is awareness of the context so as to be able to define appropriate goals. The definition of the concern for context as also a concern for relationships is helpful however because it enables the inclusion of the fundamental ethical notion developed in Chapter 3, of the *ethical-relation*. It clearly comes into focus when considering what the basis is for social construction using metaphors.

Bratton's (1992) description of the relationships formed between people, and between people and the rest of nature, uses an organismic metaphor which can be interpreted as an extension of Vickers' work. She does so by using the abstract concepts of utility values and intrinsic values. Thus it helps form a conceptual bridge between the appreciation of the ethical relation and goal-directed behaviour that was concluded to be necessary for engineering methodology in Chapter 3. She outlines two types of relationship which are never-the-less related and can be linked to the two types of feedback. Firstly there is the utilising of others (other people and other nature) as a resource. This involves a specific appreciation of the 'other' involving the valuing of them for utility for oneself. Bratton describes this as the desiring of 'need-eros'. She goes on to say however that the interaction of all need-eros between all subjects can be harmonious - or in other words, palatable eternal recurrence. Bratton describes this as the natural state which can be lost in human activity. Its loss can be defined as unethical activity. Therefore, humans are capable of appreciating others (humans and the rest of Nature) in an unethical way, by valuing them for their utility in a way which is out of harmony with the ecological system. The loss of harmony occurs when the appreciating by what is being appreciated, is not recognised and respected, i.e intrinsic values are not respected. The reflexivity of the situation has to be recognised.

Bratton outlines how the harmony can be conceived as a presence of a different sort

of valuing which is not a valuing by the perceiver but rather a valuing for the perceived. As mentioned above, her term is 'agape love' and is equivalent to that of 'affective caring' used by Heidegger (see Dreyfus 1984). When this valuing is not present as well as 'need-eros' or the valuing of utility, unethical activity results and hence disharmony and unbalance occurs. The intuitive aspect is what Bratton considers produces the integrated and harmonious activity of community. A community is where inter-subjective relationships are maintained and social functions fulfilled.

In terms of a functionalist analysis, the intuitive aspect is being engaged unconsciously to produce interactions of need-eros or utilitarian valuing that result in an integrated whole in society and with the rest of nature. These relationships are not defined by goals but rather by 'purpose' in an individual that is known intuitively as agape love, affective caring or the *ethical-relation*. The limitation of Vickers' analysis is that he does not define it in terms of how it is experienced personally in language games. Bratton's work in contrast elucidates this well.

4.2.2.2 Operationalization.

Checkland's meta-theory on which he bases SSM is that of Churchman's (1974)

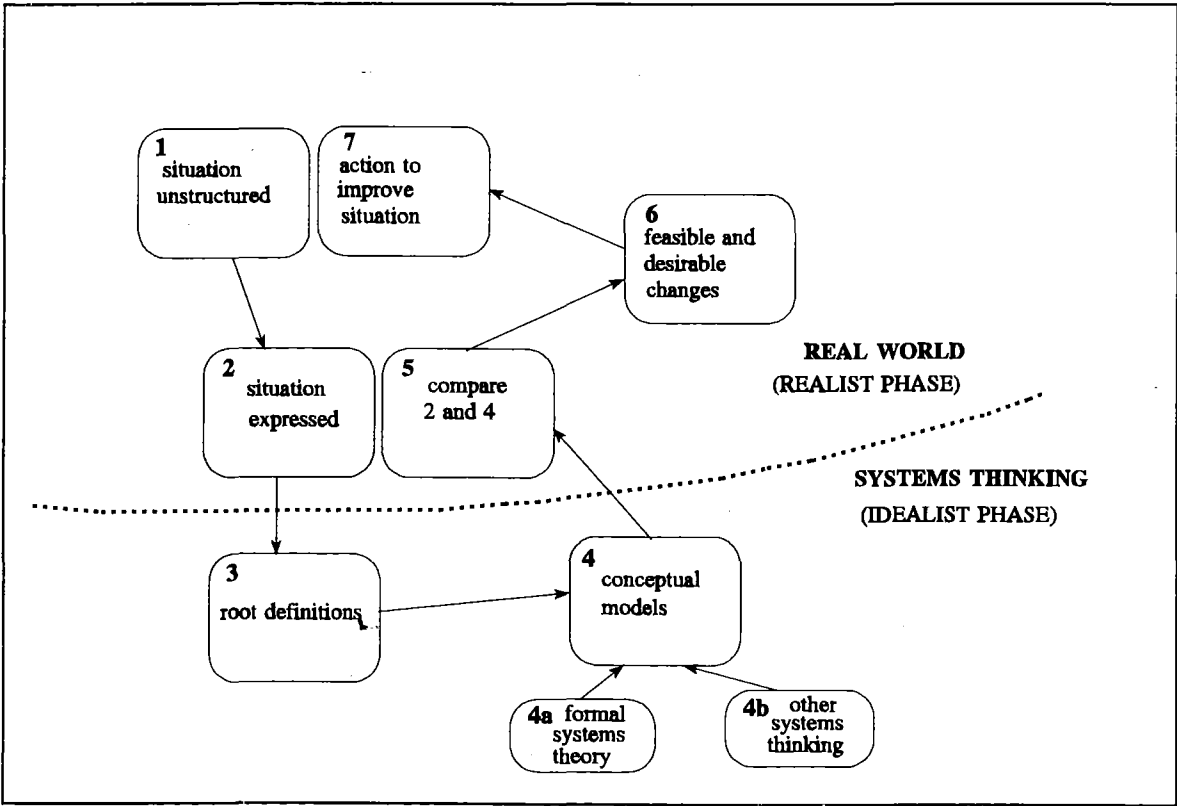


Figure 4.7; Soft Systems Methodology.

dialectic of the interaction between idealism and realism: ideals and constraints. The result is an iterative process (see Figure 4.7, after Checkland 1981; Figure 6). As mentioned above this approach is unable to distinguish between first and second-order feedbacks. This limitation is therefore perpetuated into SSM. However just as Churchman's dialectic is helpful, so is SSM useful. With development it is also able to include clarification of the distinction between types of feedback. This is best done by considering SSM as shown in Figure 4.7.

The systemic thinking (idealist phase) involves two aspects: the development of 'root definitions' and 'conceptual models'. Root definitions (RDs) are descriptions of HASs according to a meta-structure Checkland developed. He used a mnemonic (CATWOE) to outline it. Each RD must involve a recognition of: Customers, Actors, Transformation, Worldview, Owners, Environment. The first four meta-elements refer to the system. Better words are able to be used to fit the development of the theory so far. These are:

1. Stakeholders: the moral community which has intrinsic values. These are all the beings in the community that is being considered.
2. Institutions: the social organisations that are the groups or collectives which interact in the structures of power within language games.
3. Transformation: all the processes which goal-directed activity is concerned with. They are what hard system analyses are concerned with.
4. Worldview: the dominant assumptions which can be abstracted to direct the goal-directed activity of the institutions.
5. Decision-makers: those who make decisions that are enforced.
6. Environment: what is external to the system and includes beings other than the stakeholders that the stakeholders are interbeing with.

Checkland characterises a RD as describing a *how* - a purposeful activity. Several RDs can be produced for a situation so as to give different perspectives. Conceptual models (CMs) are definitions of interacting activities which express the purpose elucidated by the set of RDs associated with a situation. Checkland conceives CMs as *whats* - they are descriptions. According to Checkland, several RDs can be used to give perspectives on a CM because goals are not clearly defined in the situations that SSM considers.

Mingers (1990) however questions the what/how distinction made between RDs and CMs. Mingers argues that because RDs encapsulate worldviews they are more legitimately *whats* than *hows*. In other words the self-fulfilling nature of descriptions of HASs makes them effectively *hows*. This is arguably a better explanation of why goals



are not clearly defined. Mingers would prefer that CMs be characterised as the *hows* to achieve the *whats* of a RD. Therefore there should be several CMs for each RD. Mingers' criticism makes SSM coherent as a method to decompose systemic formulation into goal-seeking systems. However something is lost in this attempt. The richness of SSM is that it implicitly includes a non-goal seeking dimension as well. CMs can also be seen to allude to the maintaining of inter-subjective relationships that manifest ethical concerns and thus give a basis for *what* goals should be sought after synthesis from the views of different groups. Also a RD is explicitly only a heuristic device to promote seeking of helpful change - it does not claim to be a definitive description of reality (a *what*). For it to be a *what* would require it to be expressed in the terms of the group responsible for the RD and the meta-structure suggested would be inappropriate. Seeking clarification of Transformations is asking for information on goal-seeking processes. Therefore the meta-structure is itself a self-fulfilling prophecy to create clarification of goal-seeking processes groups may have.

The main agenda that Checkland makes explicit is that of Churchman's; that the task is to improve the social situation. From a postmodern point of view this means to creatively respond to intuition so as to improve language games. Checkland allows that this involves concern for the maintenance of relationships, as well as the rational concern for goal-seeking in the synthesis of a CM. Never-the-less Checkland's reliance on clarification of only goals in RDs to serve as the foundation for the synthesis of a CM does not give an adequate basis on which to ground an ethics according to Ivanov (1991).

For example the concern for inter-subjective relationships involves the introduction of trust which is not explicitly developed in SSM. Checkland is also criticized for not considering the practical aspect of operationalization sufficiently. The practical or realist phase in SSM is limited to the sharing of views to seek a common understanding in the hope that this will bring about an improvement in the situation via the decision-making process. According to Critical social theory (see Section 4.1.2.3.5), the discussing of views is not sufficient, even though it is necessary, to bring about an improvement. Mingers (1984) argues that it may make an incremental improvement, but questions whether this is adequate.

Checkland (1981), already aware of such potential criticism, argued that SSM can be used for ethical ends or otherwise depending on the purposes of the user. Mingers argues never-the-less in response that evidence needs to be sought as to whether it does actually lead to an improvement when it is the purpose of the user. Mingers (1984) suggests that explicit political activity may also be necessary.

The inadequacy of the 'mere' discussing of views mentioned by Mingers (1984) is recognised in debate about the value of *interpretive* sociology, i.e. where different interpretations or perspectives are discussed, e.g. standpoint epistemology (Fay 1975). Some Critical social theorists make the point that discussing issues in the attempt to reach a consensus may only be defusing and obscuring real injustices (e.g. Jackson 1982). Interpretive sociology may be potentially reactionary in not responding to a need to adapt because of possible attempts to change people's perceptions to accept the status quo. It has already been mentioned that 'false consciousness' is not adequately appreciated.

On the other hand, it is overlooked by criticism aimed at Checkland for using interpretative sociology, that the approach of Checkland has functional integration and metabolic health as the norm (from Vickers), which is a strong statement for social justice along with an environmental ethic. Checkland (1981) himself points out how close his view is to critical social theory. It is in fact argued later that Checkland's functionalism (also criticised by Jackson 1982) provides a more effective way to bring about improvement of situations than what Critical social theory can suggest.

#### **4.2.3 Critical systems theory. (CST)**

CST is considered by several in systems research (e.g. Ivanov 1991 and Flood and Ulrich 1990) to be a second epistemological break after Checkland's break from hard systems analysis to produce SSM. The first epistemological break involved the acceptance of a phenomenological point of view incorporating interpretive sociology. The second epistemological break involves the acceptance of several methodologies. Specifically, the acceptance of the use of a causal metaphor to give broad appreciation of causal relationships of power within society, as well as interpretive views to appreciate the different perspectives present among the actors.

The second epistemological break emphasises the need for reflection about the context of the analysis so as to consider the existence of inappropriate power and hence the possibility of the need for structural change. Whereas SSM considers the context in terms of the worldviews of the actors, and to an extent the relationships (social functions) which they participate within, CST argues for the need to also consider the social context in terms of the political reality, so as to gain an understanding of what needs to be changed so as to ethically improve the social reality.

To introduce CST it is helpful to first consider what Checkland was trying to do in making the first epistemological break. Checkland recognised that 'community' exists and he values it as a good basis for society though he does not develop a philosophy of it

because second-order system dynamics were not appreciated. What he does do though is recognise that the potential of community relationships are not fully expressed and can be improved. Therefore he argues for the need to seek to improve the situation. But he does not do this in explicitly ethical terms once again because the processes involved were not appreciated. This is where CST theorists' criticism of SSM indicates what CST is attempting to do. CST argues that ethics should be included by the use of practical reason along Kantian lines (see Chapter 3). Flood and Ulrich (1990) argue that there is a need to reflect on the social situation and apply rational ethical principles that guide action. The rationalism believed in by standpoint epistemology is equally believed in.

CST considers that the way to treat all human beings as ends and not means, according to Kantian ethics, is to give them equal access to rational discussion about what society's goals are (see Chapter 3). Participatory democracy is seen as the solution. It is assumed that if the conditions are right then a rational society will emerge. What is required is the overcoming of the unjust structures denying equal public participation. Therefore ethical concern becomes focused on political activity to overcome unjust power structures. Once this is done it is believed that rationality will do the rest because ethics is known through universal rational principles. CST therefore subsumes ethics under politics. CST seeks ethical improvement through political change that allows the use of practical reason to elucidate universal principles. These principles become the basis for decision rules. What the political change that is required is considered to be discovered through the use of critical social theory using a causal metaphor to elucidate unjust power.

The emphasis is on consensus-seeking and is the ideal that public participation in management and planning is based on. However in itself it does not guarantee an improvement in the situation. Discussion and consensus-seeking may still lead to decisions that are not good. As mentioned above, they may even result in the coercive acceptance of an unjust status quo (see Chapter 3). Churchman (1974) has also recognised this and argued that the few who would doubt a situation, that few who would question, should be especially listened to. Otherwise dogmatic beliefs arise. Postmodern commentators also point out that this places CST within the modernist paradigm where rationality is exalted as the only means for coming to knowledge, and where the premises that the rationality that is used are based on are not addressed (Ivanov 1991). In other words, only one type of discourse along lines of one type of rationality can be addressed in this way.

Argyris (1988) also points out however that political change itself is not enough to bring about ethical improvement in situations, because the individuals have to learn to

relate to reality in a way that nurtures the new activities expected of them. CST with its cognitive orientation from critical social science obscures the relationships involved in communities of care and trust. CST does not address the community dimension any better than SSM does even though it attempts to address the need to incorporate ethics explicitly. An ideal speech situation enabling rational discussion is not sufficient.

The CST hermeneutic is incomplete though it does reveal the place that power has in language games and what has to be changed in them. CST does not give any basis for bringing about the change, nor give any clear understanding about what the change should be: just that it should not be unjust. The call for 'liberation' is not adequate in itself as it merely reproduces oppression (Friere 1972). Argyris (1982) argues, with empirical evidence, that such activities are actually counter-productive as they break down trust and communication.

Fay (1975) points out, in agreement with Argyris, that the socialisation process of individuals to think and act in certain ways through their training, for example engineers, makes it extremely difficult for them to change. Any suggestion that their views may be mistaken results in aggressive reaction (due to systemic neurosis). Argyris makes the point that even if it is possible to get rational discussion within SSM as CST argues for, the 'espoused theories of action' of actors will be different to the 'theories of action in use'. The pressures of the language game to 'play the game' will override rational discussion about what should be done once the discussion is finished. Argyris claims further that this is not done consciously. It is inherent systemic neurosis which occurs unless people are trying to become individuated.

The point is that individuals need to make a commitment to change their activities if there is to be an actual improvement in the situation. Postmodern views argue that this requires a different experience of self and relationship with reality. Ontological growth seeking integration is required. Checkland's ideal of community actually takes SSM a step further than CST.

Postmodern ideas are criticised by critical social theorists for not being serious enough in their 'preoccupation with the sparkling interplay of language games' when faced with serious social injustices due to exertion of power (McLennan 1992). But in response it can be argued that sociology can not help to overcome social injustices unless it accepts the reality of language games, and works to improve the social situation through their creative change. Otherwise the attempts are counter-productive. However clarification of the political context by CST theorists using critical social theory is helpful and necessary for development of SSM so as to explicitly incorporate ethics, but the reliance on practical

reason for ethics and Critical social science is not adequate. Nurturing a commitment to ontological growth or individuation and the ethical relation are also required. A commitment to nurturing reflexivity is required. This can only come from expression of authentic authority, and not from power. Therefore the solution is not essentially political.

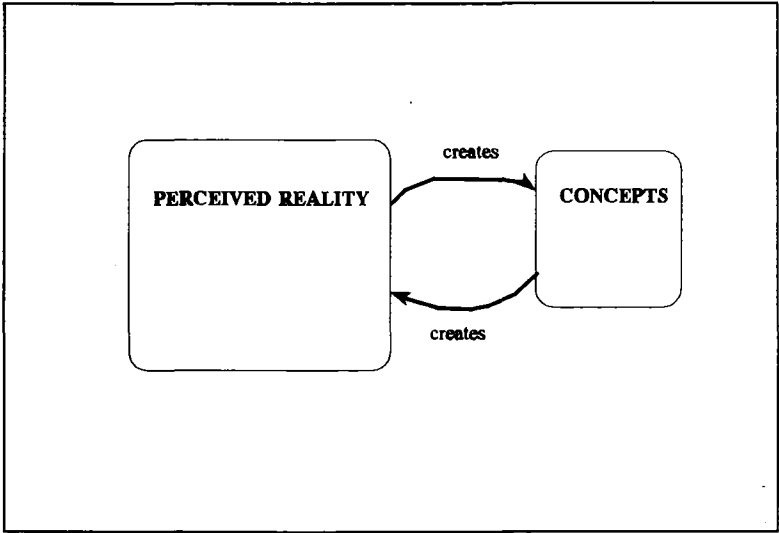
**4.2.4 A Postmodern systems theory.**

Ivanov (1991) mentions the possibility of a postmodern systems theory as a necessary improvement over CST. Ivanov mentions the process philosophy of Whitehead and the analytical tradition of Jung in psychology as possible directions for such a development. Such a development can be begun by considering Checkland’s systems philosophy. Checkland rejects Churchman’s view of a potential objective systemic reality. However he accepts the learning approach of gaining ever new systemic images of reality. Checkland considers that the real systemic reality is in the process of discovery (see Figure 4.8, after Checkland 1988b; Figure 2). A postmodern approach can accept Checkland’s systemic learning process but not the idealism, or at least implied idealism. But Checkland’s view need

not be interpreted as philosophical idealism. Such a ‘literal’ interpretation of Figure 4.8 would consider that perceptions change after thinking and the creation of new conceptual models, and that the change in perception means a change in reality. A better interpretation is given by social constructionism.

From this viewpoint another possible interpretation of

Checkland’s systemic process is the common sense and transcendental phenomenology approach that different thinking may alert a person’s attention to focus on different aspects of reality, and so perception changes. It does not necessarily mean that reality changes but that which is seen of reality changes. In this sense there is a link between thinking - socially constructed through language mostly - and perception, but without any metaphysical claims about reality.



**Figure 4.8;** Perception and conception dialectic.

Within this process of learning to look more or less carefully at reality depending on what is useful to do, and with the processes of reality expecting to change as well through co-evolution, a vast potential for differences in worldviews arises. Hence Checkland's phenomenological view assuming unique worldviews (realities) for everyone is understandable. Douglas (1986) develops this by arguing that the basis of a society is in what it considers is important to refer to - to point out. Douglas develops this in reference to natural hazards and perception of risk (see Chapter 6). It is impossible to include everything into the language game which is directing attention to aspects of reality. Therefore only certain things are focused on to give the points of conscious contact with reality. Language is used to give people a sense of reality: a collective reality to live in. It will not be a perfectly adaptable reality as not all the features of reality are labelled and brought into consciousness for people to look out for and to engage with in varying types of relationships. Therefore no language game is final and complete. There may be the need to creatively improve language games so that other features are pointed out and engaged with as natural processes evolve. Language game change is part of co-evolution. It is here that the postmodern appreciation of the basis for reconstruction in the ethical relation expressing moral freedom can be introduced. It gives rise to ontological growth and hence authentic authority (wisdom) which nurtures further growth of others. Such an approach enables ethics discourse, along with all other types of information, to be synthesized.

The other main concern postmodern thought has is for the existence of people within language games which are not adequate. Authentic authority of non-power gives an effective way to improve the perception of individuals and hence transformation of such language games. On the collective level the aim of the pragmatic postmodern radical constructivist need for concern for systemic integration and clarification of open or living systems, is to help focus on what is required to be monitored. It points out the functional role, as well as intrinsic value as a giver, of what is required to be focused on; its changeability and its ability to be changed, and what it should be changed to because the information processes giving feedback are able to be defined. Clarification of this enables reconstruction of coherent analysis.

#### **4.2.5 Reconstruction of systems.**

Postmodern system theory accepts the political context CST points out and so sees the need to analyze the emergence of power with a causal metaphor. However instead of opting for the incoherent relativistic position and rationalism of critical social science it

elucidates and develops Checkland's intuition about the importance of communities as natural systems and develops a radical constructivism through more thorough use of an organismic metaphor. It also allows expression of metaphors other than organismic and causal ones to nurture as 'language without knowledge' personal relating of the *ethical relation*.

This type of interpretation can attempt to define a meta-structure for how language can be used to frame the situation so that the language game socially constructed is ethical because it helps nurture community integration. The meta-structure is able to be framed according to the overall metaphor of reflexive spheres (Figures 4.5-6). The different spheres can be interpreted by different sets of metaphors because different interpretive processes are being sought.

The innermost one at the hub of the transcendental pole involves free use of metaphor as myth/poetry/art and vision give the premises for reconstruction of a world and rational development. There is the need for the sacredness of the transcendent pole to be recognized by these myths. Also the role of wilderness to civilise, and the telos of growth through expression of care to be responsible in wisdom and sacrifice. This innermost sphere is also the outermost however and so also defines all ends and the discussion of context in terms of intrinsic values. In between these two, the communities to be integrated within - including ecosystems - occur as the nested hierarchies of living systems. Each integrative process required for each level in the hierarchy can be helped by SSMs, and so nested SSMs result. Thus nested co-evolutionary processes of integration within interbeing are facilitated through the use of SSMs.

For each of these SSM, HSA are nested to achieve specific goals and to monitor for divergence from norms of maximum flexibility. The nesting of SSMs allows for the analysis of power with causal metaphors to indicate where change is required for improved integration. Successful integration within a system, which is the focus of any particular SSM, can overcome the emergence of power critically analyzed at a higher level system focused on by another SSM. The critical analysis of power at the higher system through SSM can help direct what the integration is that is required at the lower level. For example, to transform elite power expressed by regional council engineers may require attempts at building community relationships between them and the publics involved so that trust, dialogue and cooperation can occur. Paradoxically, once the hierarchically nested systems are recognized, authoritarian hierarchical structures abusing power can be overcome, and so moral freedom can be expressed allowing functional reconstruction.

The nesting of hard system monitoring within systems enables the significance of

negative (second-order) feedbacks to be incorporated also. The difference from critical analysis of power is that the use of causal metaphors are used to consider integration at a higher level rather than at a lower level. In terms of the example of regional councils used above, hard system analyses by engineers monitoring water quality levels is second-order feedback enabling integration into the higher level system of the ecosystems the council's human communities are part of.

The need for explicit inclusion of ethics is achieved through recognition of the innermost sphere and use of mythical language in the 'realist phase' of the SSMs to guide development of the RDs. A conceptual bridge linking these insights to goal-directed activity is achieved through the definition of all stakeholders (intrinsic values) and the construction of CMs which have hard system analyses nested within to achieve the utility values required and monitoring for second order feedback.

The decision-making model for floodplain management developed here has three nested SSM with hard system analyses nested within them (see Chapters 9 and 10).



# Logic

Logic is a formulation of types of thinking processes. It is usually linked to the process of reasoning and so describes the form associated with a particular rationality. As such it is also an expression of certain distinctions or premises that arise non-rationally and reflect particular styles of language game and relationships (see Chapters 3 and 4). Logic is then the general formulation of ways language is used to reconstruct worlds. The general forms that this can take are described. They are related to the relationships underpinning the language game and the fundamental distinctions or premises and rules giving rise to the rationality.

Most engineers are exposed to types of logic by way of inherent schemes present in calculus used with the causal metaphor and the random generator metaphor; i.e. standard calculus and probability theory. However these two logics are only two (very specialized ones) among many other possible ones that can be and are used. For example in the management process there are those involving the use of the organismic metaphor and mythical metaphors - all necessary for coherent methodology (see Chapters 3 and 4). Of special interest are logics associated with the meditative process seeking reflexive coherence and wisdom - the fundamental thought processes of deconstruction and reconstruction. Also important are logics which can give form to a philosophy of science that is empiricist and reflexively aware that its theories explicitly use a causal metaphor and are of vague trends of varying degrees of imprecision. To the extent that logic can be formalized then these different ways of thinking can be formulated into a general methodology. Because the development of a general methodology is the aim of this research, clarification and development of the logics used by engineers are important.

There are two broad traditions in the literature on logic. They can be summed up as the Indian and Western traditions.

## 5.1 INDIAN LOGIC

We will deal with the Indian tradition first as it gives a helpful typology for understanding the broad types of thinking that are reviewed in Chapters 3 and 4, though some development is required. The following brief sketch comes from Govinda (1976). Indian logic allows for four truth states:

1. True
2. False
3. True and false.
4. Not true and not false

These states refer to the truth value of statements. The truth value refers to a relationship between the meaning of the statement and to what the meaning is referring, i.e. it relates the two aspects involved in phenomenological epistemology (see Chapter 4). Hence by exploring how truth is used in various logics the meaning of truth as a concept in model-making for decision-making can be ascertained. However it can be expected to have to be deconstructed dialectically to avoid criticism of using a naturalistic legitimation for truth (Emery 1981 and Wright 1991). From the perspective of pragmatic radical constructivism developed in Chapters 3 and 4, truth is a meta-concept which can never-the-less be useful if used in context. The value or usefulness of the concept of truth is that it can be used as a standard on which to make decisions. Care has to be taken, because of its role to legitimize social construction, to make sure that it is used appropriately in context and not ideologically as an expression of the abuse of power (see Chapters 3 and 4).

A 'true' statement means that the meaning of the statement agrees with what the reality is that the statement is referring to. A 'false' statement means that the meaning of the statement does not agree with what the reality is that the statement is referring to. A 'not true nor not false' statement is one that is explicitly metaphorical and uses mythical metaphors. On the literal level, or rationality of the prior text, it is 'not true', however on the level of analogy it is 'not false'. For example statements that claim a river is a *taniwha* (spirit) are examples. Such statements attempt to bridge worlds. It is how depth experience and wisdom is described (see Chapter 3). Descriptions may be paradoxical. The description of the hermeneutic circle is an example. 'The whole is known by the parts and the parts known by the whole'. A hermeneutic of respect is used to elucidate these statements so that a fuller depth of the difficult to express, yet important, meaning can be grasped.

A 'true and false' statement is one whose meaning is meant to have an effect which is distinct from the straightforward meaning that the statement has. These statements are distinct from 'not true and not false' statements in that there is not any attempt to relate or transform worlds. Rather the statements are trying to delude by ignoring aspects that are pertinent. Literally they may be true but they do not refer to depth experience involving intuition. The statements may for example be tautologically true, but the real intent is not

to merely define terms, but rather to make a masked normative point and to influence activity in a manipulative way. Coercive ideology uses statements like this. Conclusions from the use of hard systems analyses or cybernetics where second-order feedback from the wider system or environment is ignored are examples (see Chapter 4). A hermeneutic of suspicion is used to interpret these statements and to restate them so that masked normative intent or lack of appreciation of context is revealed.

From the empiricist approach developed in previous chapters it is difficult to claim any statements that are true as all is seen to be metaphor. So there may be an argument to extend 'not true nor not false' to include all explicit use of metaphor, including when causal, organic and random generator metaphors are used. The inherent vagueness is expressed in its 'not true nor not false' truth value in comparison with a Popperian approach which would claim it to be a 'true' belief (see Chapter 4). This extension would require that the way metaphors are used be coherent and so the context is appreciated and so all statements are integrated into expressions of wisdom. In other words, all useful statements are wise in context. Statements which are 'false' are those which are incoherent, and so are not wise. The inability to have perfectly true or false statements is later shown to be why there is the need for fuzzy logic.

## **5.2 THE WESTERN TRADITION**

In the Western tradition formal logic goes back to Aristotle (see Rescher (1969) for a historical review). Unlike in Indian logic, the dimensions of the types of thinking embraced in Chapters 3 and 4 are not present. Its formation by Aristotle makes this not surprising because Aristotle explicitly separated descriptive statements from normative statements in a way which made appreciation of wisdom difficult (see Chapters 3 and 4).

Aristotle's concern with logic revolved around the world of form. Therefore an issue was contingency. He argued that statements about the future could not be true nor could they be false because they had not happened yet, and so they were indeterminate. This focus has formed the basis of the Western tradition (Rescher 1969). For Aristotle there were therefore three truth states:

1. True
2. Indeterminate
3. False

Never-the-less Aristotle's view has always been the minor tradition of logic in the West. Binary logic has been the dominant tradition. It started during the Middle ages when Aristotelian thought was reintroduced into Western thought. This was because future

indeterminacy was taken to mean a lack of omniscience on God's part. This was because Aquinas argued that any apparent indeterminacy was in reality merely ignorance. It was dogmatically held that all was determined by God. This view assumes a type of rationalist epistemology, but by 'fallen minds'. This view was continued in modern science which has shared Aquinas' deterministic views. However Descartes did not share the same view of the fallenness of human minds that Aquinas had, and claimed that reason is able to have the mind of God and hence to discover the determinism in the world. Newton attempted to carry this out and some scientists have been attempting to discover this absolute truth ever since. There is the assumption and hope that one day human 'ignorance' will be swept away by the truth that science will bring and give the ability to perfectly control nature to fulfil our ends. The future will no longer be indeterminate. Technological utopia will be achieved (see Chapters 3 and 4).

### **5.2.1 Multi-valued logics (MVL).**

Never-the-less, non-binary or multi-valued logics (MVL) did persevere in the West alongside the binary dominant tradition. Rescher (1969) has also reviewed the development of multi-valued logics in the Western tradition. A relevant precis is included here. There were two main sub-traditions: the alethic and probabilistic. From the alethic modalities traditional MVL were developed, and from the probabilistic modalities probability logic. Rescher (1969) argues in contrast to others (e.g. Gaines 1976 and Dubois and Prade 1988) that probability logic is actually able to be labelled a MVL; just different to those derived from the alethic modalities. This view is held here for ease of commentating on the typology. The oldest are however the alethic modalities and were developed by Aristotle:

Necessarily true

Contingently true (i.e. actually but not necessarily true.)

Contingently false (i.e. actually but not necessarily false.)

Necessarily false.

The probabilistic modalities are:

Certainly true

Probably true

Indifferent

Probably false

Certainly false

5.2.1.1 Alethic modalities.

Alethic modalities' concern for necessary truth links it to perception of causal interactions. Technically this refers to *truth functionality*, i.e. that the truth of compound statements can be deduced from the parts, which is how the causal (or mechanistic) metaphor is constructed to form the language game of the reductionist scientific method. Lukasiewicz developed Aristotle's notion of real future contingency into a 3-valued logic with true, false and intermediate (see Rescher 1969). To make this claim requires that it is considered that the mind can know whether the future is contingent or not. Thus it assumes a rationalist epistemology. The truth table for this is given in Table 5.1. See the List of Symbols (p ) for definition of the symbols used.

p	$\neg p$	$q/p$	$p \wedge q$ T I F	$p \vee q$ T I F	$p \rightarrow q$ T I F	$p \leftrightarrow q$ T I F
T	F	T	T I F	T T T	T I F	T I F
I	I	I	I I F	T I I	T T I	I T I
F	T	F	F F F	T I F	T T T	F I T

Table 5.1; Lukasiewicz' 3-valued truth table.

In Table 5.1 truth is represented by T, false by F and intermediate by I, but to carry out a calculus of the values, true is represented by 1, false by 0 and intermediate by 0.5. Also a shorthand way of representing the truth of a statement is represented by enclosing it in back slashes, e.g the truth value of  $p \rightarrow q$  is represented by  $/p \rightarrow q/$ .

Other 3-valued logics also have been developed with different epistemological claims. For example Bochvar (see Table 5.2) developed one where the intermediate value was interpreted as meaning paradoxical or meaningless statements. Bochvar's logic does not refer to statements concerned with contingency, but rather with cross purposes or incoherence of metaphor. The 'true and false' and 'not true nor not false' are well described according to Bochvar's scheme as I values.

Kleene (see Table 5.3) developed another version of 3-valued logic and explicitly argued that the I value is not referring to real contingency but rather to ignorance in keeping with Aquinas and the resulting rationalist scientific tradition. It is not excluded that propositions may in fact be true or false, but only that the specific truth value is

unknown or indeterminate. Therefore whereas in the ‘material’ (see Rescher 1969) implication of Lukasiewicz  $/0.5 \rightarrow 0.5/ = 1$  in Kleene’s system  $/0.5 \rightarrow 0.5/ = 0.5$  or unknowing or epistemological indeterminacy.

p	¬p	q\p	p∧q T I F	p∨q T I F	p→q T I F	p↔q T I F
T	F	T	T I F	T I T	T I F	T I F
I	I	I	I I I	I I I	I I I	I I I
F	T	F	F I F	T I F	T I T	F I T

**Table 5.2;** Bochvvar’s 3-valued truth table.

p	¬p	q\p	p∧q T I F	p∨q T I F	p→q T I F	p↔q T I F
T	F	T	T I F	T T T	T I F	T I F
I	I	I	I I F	T I I	T I I	I I I
F	T	F	F F F	T I F	T T T	F I T

**Table 5.3;** Kleene’s 3-valued truth table.

Heyting (see Table 5.4) produced a significant 3-valued logic which is related to intuitionist mathematical theory (see Heyting 1971 for an introduction to intuitionist mathematical theory). This approach is significant as intuitionist logic assumes that systems (including logic systems) are mentally constructed as inherently unjustifiable distinctions in keeping with Elms (1989), Wilden (1980) and Gaines and Shaw (1987). An intuitionist theory for the philosophy of mathematics overcomes the reflexive dilemma Godel’s (see Hofstadter 1979 and Stewart 1975) proofs show is unavoidable, by placing mathematics as a language in the context of its use for modelling It is a type of constructivist philosophy.

It is similar to Bochvar’s logic and can also be used to incorporate ‘true and false’ and ‘not true nor not false’ truth values. But instead of leaving all indeterminate values to

result in indeterminacy, discernment through the use of intuition is used to tighten the values associated.

p	¬p	q\p	p∧q T I F	p∨q T I F	p→q T I F	p↔q T I F
T	F	T	T I F	T T T	T I F	T I F
I	I	I	I I F	T I I	T T I	I T F
F	T	F	F F F	T I F	T T T	F F T

**Table 5.4;** Heyting’s 3-valued truth table.

Lukasiewicz generalised his 3-valued logic to infinite-valued logic. The truth tables are given by the general axioms:

$$\begin{aligned} / \neg A / &= 1 - / A / \\ / A \wedge B / &= \min ( / A /, / B / ) \\ &= / A / \wedge / B / \\ / A \vee B / &= \max ( / A /, / B / ) \\ &= / A / \vee / B / \\ / A \rightarrow B / &= \min ( 1, 1 - / A / + / B / ) \\ &= 1 \wedge ( 1 - / A / + / B / ) \\ / A \leftrightarrow B / &= / ( A \rightarrow B ) \wedge ( B \rightarrow A ) / \\ &= \min ( 1 - / A / + / B /, 1 + / A / - / B / ) \end{aligned}$$

Gödel similarly produced an infinite valued logic which is a generalisation of Heyting’s 3-valued case. The axioms are:

$$\begin{aligned} / \neg A / &= \begin{matrix} 1 \text{ if } / A / = 0 \\ 0 \text{ if } / A / \neq 0 \end{matrix} \\ / A \wedge B / &= \min ( / A /, / B / ) \\ / A \vee B / &= \max ( / A /, / B / ) \\ / A \rightarrow B / &= \begin{matrix} 1 \text{ if } / A / \leq / B / \\ = / B / \text{ if } / A / > / B / \end{matrix} \\ / A \leftrightarrow B / &= / ( A \rightarrow B ) \wedge ( B \rightarrow A ) / \\ &= \begin{matrix} 1 \text{ if } / A / = / B / \\ = \min ( / A /, / B / ) \text{ if } / A / \neq / B / \end{matrix} \end{aligned}$$

Bandler and Kohout (1981) have outlined eight different infinite valued logics which have been used. A point to be taken from this is that there is not a clear consensus on what form of MVL is appropriate. The clarification of where different logics are appropriate has begun but is not definitive. For example Dubois and Prade (1988) favour Godel's logic, but Blockley (1980) uses Lukasiewicz'. It is not yet clear whether or not the use of different MVLs for different modelling situations has a significant effect, but a priori some conclusions can be made. Firstly that the use of MVLs is an abstraction to formalize the use of metaphor and so there can be no expectation that there is a universally correct one. But for explicit use of causal metaphor for modelling according to constructivist epistemology developed in Chapters 3 and 4, the generalization of Lukasiewicz' system is appropriate. Even though an ontic claim that real indeterminacy exists that Lukasiewicz' logic assumes is not wanted to be made by constructivism it is the appropriate working hypothesis when using an empiricist epistemology as in constructivism. The alternative in Kleene's system, while not making ontic claims, assumes a critical rationalism that can potentially discover a deterministic world, which is a less palatable working hypothesis because plurality of metaphor is employed thus determinism is definitely not assumed. For the structuring of the use of metaphor and the formulation of rules for decision-making Godel's logic is appropriate because the intuitive aspect enabling the insights associated with 'true and false' and 'not true nor not false' states are incorporated.

These MVLs developed from the alethic modalities have begun to be formalized in 'possibility theory'. Mathematically this began through the development of fuzzy sets begun by L. Zadeh, and first published in 1965.

### **5.2.1.2 Probabilistic modalities.**

Probabilistic logic is a type of MVL different from those developed from the alethic modalities because truth tables cannot be formed. This is because causal relations are not perceived and so a causal metaphor is not used. Rather a random generator is used. This is because truth functionality allowing the truth of compound statements to be uniquely determined does not hold. Rescher (1969) gives an example to show that probability logic does not have truth functionality.

The probability, represented by  $P(p)$ , is a type of truth value of the proposition  $p$ . The axioms are those for probability theory. The basic premises (distinctions) postulated and which give rise to probabilistic mathematical theory so as to structure the use of a random generator metaphor are:



1.  $0 \leq P(p)$  for  $p$
2.  $P(p \vee \neg p) = 1$
3.  $P(p \vee q) = P(p) + P(q)$  provided  $p$  and  $q$  are mutually exclusive.
4.  $P(p) = P(q)$  when  $p$  and  $q$  are logically equivalent.

Premise 2 is termed the law of the excluded middle or the law of contradiction and is a feature not found in MVLs based on the alethic modalities. It is what requires probabilistic facts to be discrete and to form a partition of possible events. Premise 3 indicates lack of truth functionality as independence showing complete lack of causal trends between discrete facts is modelled by the random generator.

### 5.3 THE USE OF LOGIC

Gaines (1983) has suggested an axiomatic description of relationships between probability, fuzzy logic and binary logic. It was developed by Gaines and Shaw (1987). Gaines started by considering the most general form of logic based on the acceptance of all that can be comprehended as objective observation. He used the view of systems held by Wilden (1980) that these are distinctions made that bring an ontological world into existence. He suggested a 'standard uncertainty logic' (SUL) which satisfies the requirement that comprehension be a priori but does not claim to be unique. SUL attempts to allow the modelling of uncertainty and imprecision in which life's situations are faced and thought about and interacted with. Consequences in general are neither certain nor precise. The task of science is to seek the special situations where relatively greater degrees of certainty seen as trends using a causal metaphor can be gained. However SUL is not as general as logic as some modelling requires. SUL has the axiom (Gaines 1983) that  $\neg p = 1 - p$ . Possibility theory as it has been developed for modelling is more general and only claims that  $\neg p \geq 1 - p$ . Never-the-less SUL enables the incorporation of the two requirements of truth functionality and the law of contradiction to be analyzed axiomatically and indicates some of the relationships between them.

#### 5.3.1 Truth functionality and the Law of Contradiction.

Truth functionality refers to the ability to make uniquely determined conclusions from propositional connectives (e.g inference as used in a causal metaphor) and all compound connectives, i.e. to have consistent consequences represented by functions without the need for further information about the origin or relationships producing the initial results. A structure independent of specific context is formalized. It is required for the development of a scientific theory which by definition is a social construction

producing repeatable results. This is not normally the case with uncertain events unless further information is added which may not be possible, e.g. in SUL which models comprehension of pure perception. For example in floodplain management the 'flood damage paradox' exists where expected damage has proven to be indeterminate. A probability density function of flood levels can be synthesized from statistical data. The expected damage from flooding can be determined from an integration of the damage-flood level (stage) relationship and probability density function of flood levels if both the damage-stage relationship and the pdf are independent of any engineering work carried out with the information. But they are not independent and so standard mathematical techniques involving binary logic in integration cannot determine an answer. Paradox results and Bochvar's MVL applies. What also needs to be known is how the damage-stage relationship is related to the construction of stop banks constructed to optimise the benefit based on calculations assuming independence of the two relationships described. The paradox is an example of observer effect on objective reality. The dependence of damage-stage relationships on how they will be used means that the reasoning of what is optimum, based on damage-stage and probability density function relationships, is not truth functional. A reflexive situation occurs which makes the system open.

The law of contradiction or law of excluded middle states that something cannot be true and false at the same time. This does not allow the modelling of imprecise uncertain events either. Defining imprecise concepts, e.g. a 'flood requiring evacuation' means that some floods may be in the middle and will result in controversy as to whether evacuation is needed or not. That evacuation is needed is both (or neither) true and false. An intermediate value is required as Bochvar recognized. Vague or imprecise concepts where the law of contradiction do not occur emerge out of situations where truth functionality does not occur (often due to reflexivity). For example in Chapter 8 a mathematics using a MVL to describe vague trends in the open system giving the flood damage paradox enables an answer to be produced. But it is vague. Thus a relationship between certainty and precision arises due to the level or system in which a concept is framed. This is formalized in Chapter 9. It is one of the central discoveries of this research and is found to be important for development of integrated decision-making models.

Truth functionality without fulfilling the law of contradiction gives rise to the MVL from the alethic modalities, e.g. possibility theory and fuzzy set theory (Gaines and Shaw 1987). Fulfilling the law of contradiction but without having truth functionality gives rise to probabilistic logic. With both truth functionality and observance of the law of contradiction the result is binary logic of deterministic calculus as developed by Newton in

the rationalist scientific tradition (see Chapter 4). Awareness of the axiomatic structure given by these principles to logics and mathematical tools as well as the metaphors associated allows for better mathematical modelling to be carried out.

However this is not a complete appreciation of how the types of logic can be used for modelling. This can be appreciated by exploration of a different axiomatic approach (other than SUL). It can show that probabilistic logic is special case of MVL deriving from the alethic modalities (see Section 5.4). The implication of it is that a random generator metaphor is as fundamental as a causal one and so it is not only the result of deterministic chaos in a complex open system (see Chapter 4). This result is helpful in developing formally the relationship between certainty and precision already mentioned in terms of the hierarchy of systems (see Chapter 9). However that standard mathematical calculus includes both is universally held. That it is a special case indicates clearly why scientific modelling according to standard mathematical calculus, as has been done since Newton in the rationalist scientific tradition, is problematic or of limited application. Rescher (1976) has formalized an argument to show this, which Blockley (1980) has reviewed. It is developed below:

Assuming a unique truth means that a single true hypothesis is possible. Therefore other hypotheses will be unique and separate from it. Therefore the truth values for different hypotheses can be legitimately modelled by a probabilistic analysis of independent events. Let A be an hypothesis and let X be the source of all tests on the hypothesis. If it is accepted that scientific method gives a unique true hypothesis, then  $P(A | X \text{ maintains } A) \approx 1$ . Now,

$$P(A | X \text{ maintains } A) \cdot P(X \text{ maintains } A) = P(X \text{ maintains } A | A) \cdot P(A)$$

$$\Rightarrow P(A) = \frac{P(A | X \text{ maintains } A) \cdot P(X \text{ maintains } A)}{P(X \text{ maintains } A | A)}$$

$$\approx \frac{P(X \text{ maintains } A)}{P(X \text{ maintains } A | A)}, \text{ as } P(A | X \text{ maintains } A) \approx 1$$

$\therefore$  if  $P(A)$  is high,  $\approx 1$ , i.e. that A is the unique true hypothesis,

$$\Rightarrow P(X \text{ maintains } A) \approx P(X \text{ maintains } A | A)$$

$\therefore$  That X maintains A, and that A is the unique true hypothesis are independent. This means that the scientific validation that X maintains A has no relationship to the unique truth of A. Therefore no induction can be carried out from experimentation or any other collection of data. But it is in contradiction with the assumption made that  $P(A | X$

maintains A)  $\approx 1$ . Therefore it has to be concluded that the original assumptions are incoherent. It cannot be assumed that a unique true hypothesis can be given. This in turn agrees with Popper's evolutionary critical rationalism, but rejects the notion of rationalism as an epistemology.

Blockley (1980) concluded when reviewing Rescher's (1976) argument that it meant that the situation cannot be considered probabilistically as rationalism would require it. However Blockley misses the added point that it can be interpreted differently: that making precise claims (defining precise concepts implementing the Law of Contradiction) is incoherent when trying to socially construct knowledge according to the scientific method. Rescher (1976) also misses the different interpretation by claiming that it vindicates Popper's (1958) rejection of inductive reasoning. In fact an empiricist epistemology based on inductive reasoning which explicitly uses metaphors, and therefore adds imprecision into conceptualization, can avoid the incoherence.

To include imprecision however requires the use of possibility theory. Using development of possibility theory (Equations 5.1-3), from Dubois and Prade (1988), the argument below shows how inductive reasoning is coherent when used in social construction of scientific hypotheses according to an empiricist epistemology rather than a rationalist one.

$$\begin{aligned}\Pi(q | p) &= 1 \text{ if } \Pi(p) = \Pi(p \wedge q) \\ &= \Pi(p \wedge q) \text{ otherwise.}\end{aligned}\quad (5.1)$$

$$\Pi(p \wedge q) = 1 - N(p \rightarrow \neg q) \quad (5.2)$$

$$\begin{aligned}\therefore \Pi(\neg q | q) &= 1 \text{ if } \Pi(p) = \Pi(p \wedge \neg q) \\ &= 1 - N(p \rightarrow q) \text{ otherwise.}\end{aligned}\quad (5.3)$$

Let A be an hypothesis, but not in the sense of attempting to be the unique true one, and let X be the source of all tests on the hypothesis. So, from Equation 5.1:

$$\begin{aligned}\Pi(\neg A | X \text{ maintains } A) &= 1 \\ \text{if } \Pi(X \text{ maintains } A) &= \Pi(X \text{ maintains } A \wedge \neg A) \\ \text{and } \Pi(\neg A | X \text{ maintains } A) &= 1 - N(X \text{ maintains } A \rightarrow A) \text{ otherwise.} \\ \therefore \text{ if } \Pi(X \text{ maintains } A) &\neq \Pi(X \text{ maintains } A \wedge \neg A) \text{ (which is assumed in accepting the} \\ &\text{use of induction)} \\ \Rightarrow N(X \text{ maintains } A \rightarrow A) &= 1 - \Pi(\neg A | X \text{ maintains } A)\end{aligned}$$

Now, if there is confidence in the testing of A, i.e. if induction is considered legitimate,

$$\begin{aligned}\Pi(\neg A | X \text{ maintains } A) &\approx 0 \\ \Rightarrow N(X \text{ maintains } A \rightarrow A) &\approx 1\end{aligned}$$

However whether or not A is considered to be true, and whether or not there is confidence

in the testing procedure can only be answered subjectively, and is not bound to any particular method. All creation of hypotheses and testing of hypotheses can be seen to be social construction.

So it can be concluded that scientific method can be coherent but the use of standard mathematical calculus to model hypotheses is incoherent unless used to model phenomenological ideals (see Chapter 4). This is not just a philosophical subtlety. It has ideological consequences. It is later shown that models using inappropriate mathematics lose their value as models. If that they are false as well as true is not recognized they can be taken out of context and so not used appropriately or wisely. The different types of logic and their development into mathematics give different methods to express relationships represented by different types of metaphor. They are different designed abstract systems (see Chapter 4). This is how an intuitionist philosophy of mathematics interprets mathematics in general. The validity of a particular mathematics is the context in which it is being applied: whether possibilistic, probabilistic or standard calculus.

When the context is a very open system (or fundamentally random) and a random generator is used, the appropriate logic is probabilistic and the mathematics that is appropriate to apply is probability theory and statistics. But the modelling limits the analysis to discrete events. This model of uncertainty is appropriate and helpful when considering disperse 'atoms' of information, i.e. where underlying relationships are considered to be so weak that independence can be assumed and so the 'atomic' events can be considered to be random and discrete. It is the model of uncertainty used in stochastic modelling. For example, one way of considering the flood damage paradox is to model the action of engineers in constructing floodbanks and the action by publics on the floodplain as random events. It is the statistical approach critical social science uses when testing the null hypothesis that the use of a causal metaphor to indicate causal trends is insignificant (see Chapter 4).

When a nearly closed system is being modelled, and a causal metaphor is used, a possibilistic logic is appropriate. Possibilistic logic has truth functionality. Therefore some relationship between the events is assumed. The truth functionality is not precise however. Degrees of truth can exist in functions including implication and inference because the law of contradiction is not incorporated. Gaines (1976) has reviewed why 'fuzzy' logic is required in considering everyday issues. For example the level of a flood requiring evacuation. If fuzzy logic is not used Zeno's paradox occurs. If a definition of a flood not requiring evacuation can be made, and if adding 1 mm to the stage level will not change the definition then no flood will ever require evacuation. A fuzzy logic

implication allows the absurdity to be resolved and is of course what is done in practice intuitively. The value of fuzzy logic is that it can handle imprecision yet still allow inferences to be made. Such a fuzzy use of the causal metaphor is appropriate when there is different evidence pertaining to concepts. For example expert subjective evaluation of concepts that form a vague relationship. Aggregation of subjective evaluations using fuzzy sets is straight forward (see Chapter 7 and 9).

When a closed system is modelled it may be appropriate to use a non-fuzzy causal metaphor as a phenomenological ideal so as to allow for the complex development that the premises allow. But it has to be recognized that the inherent imprecision, no matter how small, will produce counter-intuitive results eventually and even chaotic events if too complicated. Such a situation may be appropriate to be modelled in this way if a possibilistic logic of vague trends appears to be very precise, or if a probabilistic logic used with discrete objects to test a null hypothesis finds that there are causal relationships between them. But these are achieved only in special situations. Most of the time uncertainty about what is actually being defined, means that control and power accruing from the information is limited. Of course this is not a bad thing (see Chapter 3). It means that engagement with reality is mostly not in a manipulative fashion but rather has to be in a cooperative manner expressing moral freedom and the ethical relation seeking integration. It is helpful to note here that a coercive ideological situation occurs when manipulation is being attempted where it is not actually possible. It is an expression of the technocratic myth (see Chapter 3). To carry out control requires social coercion to deny reality: to ignore context and the environment. Or in other words, to deny ontological integrity and to cease to personally grow in individuation. Ideology occurs wherever uncertainty is obscured or masked. Therefore there is a special need to be cautious in the use of this type of modelling. This is especially an issue in the concern for floodplain management because it is never-the-less the dominant form taught to engineers.

## 5.4 UNCERTAIN INFORMATION

As mentioned above, Dubois and Prade (1988) have reviewed an alternative axiomatic way that uncertainty and imprecision have been considered since Aristotle. They began by considering the way several terms are used to describe uncertainty in conversation as distinct from technical discourse, e.g.; possible, probable, plausible, credible, necessary. 'Possible' and 'necessary' and their relationship were defined by Aristotle thus: if an event is necessary then its contrary is impossible, i.e. if  $N(p) > 0$  then  $\Pi(\neg p) = 0$ . Other objective and subjective interpretations can also be given. In

possibilistic logic it is the subjective interpretations which are used. For example *possible* is a judgement which does not involve much commitment. *Necessary* almost amounts to certainty. *Probable* is used both objectively and subjectively. Objectively it refers to statistical data and the frequency of the occurrence of the event. Subjectively it refers to a judgement equivalent to likely. *Credible* and *plausible* are specifically subjective yet refer to inference able to be made from existing knowledge. Other terms are also used e.g.; confidence, belief, likely and conceivable. Conceivable is close to plausible. Degrees of belief are close to credibility.

Dubois and Prade argue that the most general requirements for a coherent definition of the truth of any statement, common to all the above views, fulfil these three requirements:

1.  $g(\emptyset) = 0$
2.  $g(\mathcal{F}) = 1$
3. If  $p \rightarrow q$  then  $g(q) \geq g(p)$

where  $g$  is a measure of confidence on  $[0,1]$  and  $p, q \in \mathcal{F}$ .

They continued to explore how it is possible to construct a grammar of the above terms to fulfil these by introducing measures of belief as a truth value.

Let  $m(p)$  be belief held in  $p$ , where  $m(\emptyset) = 0$  and  $\sum m(p_i) = 1$ . From this definition all the mathematical formulations of truth values can be derived showing their differences in assumptions. Using the terminology 'p entails q' to mean  $p \rightarrow q = 1$  then credibility of q is defined by:

$$\forall q \in \mathcal{F} \quad Cr(q) = \sum_{p \text{ entails } q} m(p) \quad (5.4)$$

i.e. the credibility of q is given by the evidence for it being true. Similarly the plausibility of q is defined by:

$$\forall q \in \mathcal{F} \quad Pl(q) = \sum_{p \text{ doesn't entail } q} m(p) \quad (5.5)$$

i.e. plausibility occurs from evidence which does not contradict. In the special case where every proposition is incompatible with every proposition not entailed by it, i.e:

$$\forall p \in \{p \mid m(p) > 0\}, \forall q, \text{ if } p \rightarrow q \neq 1 \text{ then } p \wedge q = 0$$

values of compatibility equal values of plausibility which is the special case of probability.

In this case there is a partition of the domain into discrete and hence precise sets and therefore the Law of Contradiction or Excluded Middle holds.

Another special case is when measures of plausibility can be considered to form a nested sequence of sets giving monotonicity which is the special case of possibility ( $\Pi$ ). Similarly credibility gives rise to measures of necessity ( $N$ ).

Dubois and Prade make the point that when considering probability from this perspective it involves the analysis of the uncertainty of separate elements, i.e. fuzzy points. This enables yet another possible relation between probability and possibility to be defined. It posits the use of a random generator metaphor as the most fundamental. The use of a causal metaphor from this perspective can only be fuzzy and is only a feature of monotonicity that may arise in definition of sets. Possibility is concerned with ‘focal elements’, say  $E_i$ , which are subsets of  $\mathcal{F}$  but which are not the ‘singleton’ fundamental discrete independent elements of the set which probability is concerned with. Rather they consist of a group of the elementary elements probability is concerned with. Therefore probability measures given to focal elements do not enable the specific distribution of probability of each element to be defined. Let  $m(E_i)$  be the global allocation of probability to the set of elementary events making up  $E_i$ . Therefore when considering the probability of an event, say  $A$ , which comprises a set of focal elements, the probability of  $A$  is imprecise. However the probability of  $A$  can be given the interval  $[Pr_*(A), Pr^*(A)]$  where:

$$P_*(A) = \sum_{E_i \subset A} m(E_i) \quad (5.6)$$

$$P^*(A) = \sum_{E_i \cup A \neq \emptyset} m(E_i) \quad (5.7)$$

$P_*(A)$  refers to the sum of the probabilities which imply  $A$ , i.e. make  $A$  *necessary*.  $P^*(A)$  refers to the sum of the probabilities which make the occurrence of  $A$  *possible*. Therefore Equation 5.6 refers to  $N(A)$  and Equation 5.7 refers to  $\Pi(A)$  if  $E_i$  are monotonic. A feature of this is that:

$$\forall A, \Pi(A) = 1 - N(\neg A) \quad (5.8)$$

The family of nested focal sets arising from monotonicity form the family of ‘ $\alpha$ -level cuts’ of a fuzzy set (see Figure 5.1). If the focal elements  $E_i$  are themselves singleton fundamental elements then  $\Pi(A) = N(A) = Pr(A)$ , i.e. possibility refers to a fuzzy set where imprecision occurs and probability refers to discrete fuzzy points. Another consequence is that  $\Pi(\neg A) \geq 1 - \Pi(A)$  which is a more general result than that given by SUL. Therefore possibly SUL’s view that posits causality as fundamental is not as

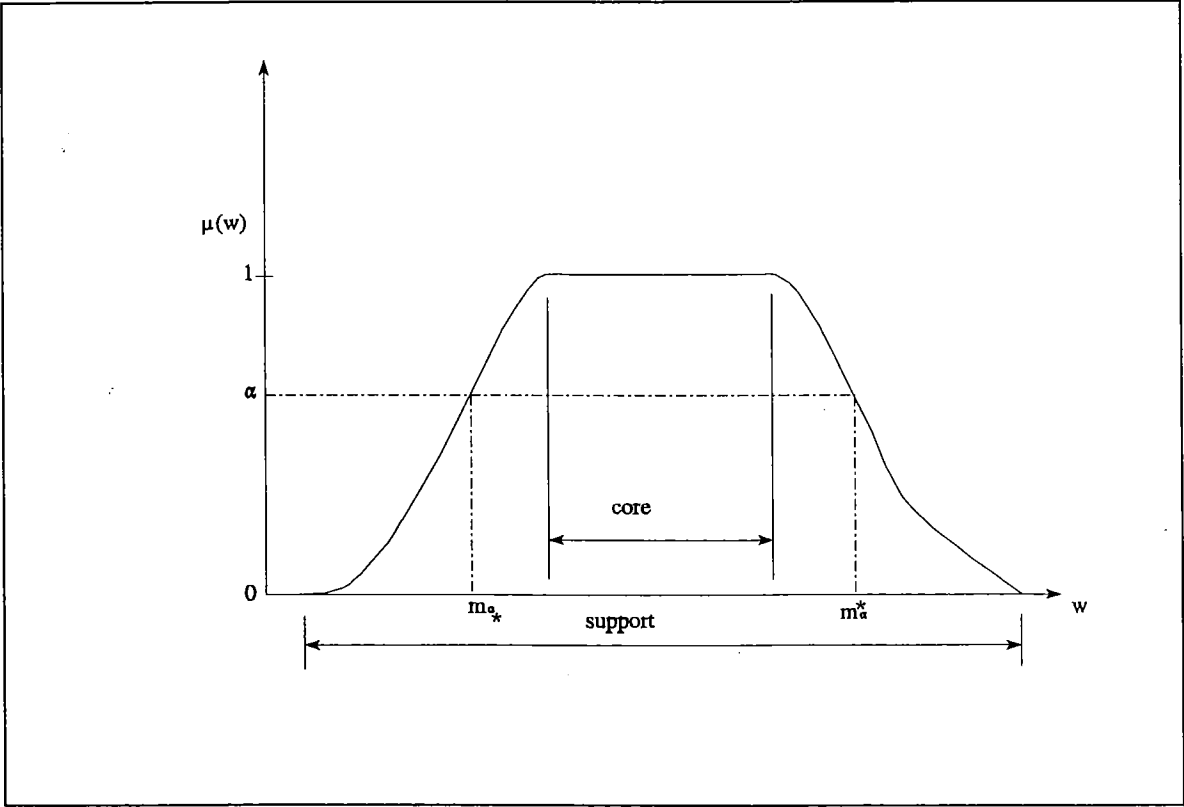


general as having randomness as fundamental. A theory developed in Chapter 9 has the two as equally fundamental in keeping with GST which considers that the metaphors image equally emergent properties.

### 5.4.1 Fuzzy sets as a degree of membership of a set.

Consider the reference set  $\mathcal{F}$ . A fuzzy set is defined by making a mapping,  $\mu_F$ , of  $\mathcal{F}$  onto  $[0,1]$ .  $\mu_F(w)$ , for  $w \in \mathcal{F}$ , can be interpreted as the degree of membership of  $w$  in the fuzzy set  $F$ .  $\mu_F(w)$  expresses how much the value (or the object)  $w$  is compatible with the concept  $F$ . In other words it formally allows definition of imprecision. This approach is equivalent to standard set theory if specific levels of membership are considered. When  $\mu_F(w) \in \{0,1\} \ \forall w$ ;  $F$  is the same as an ordinary subset of  $\mathcal{F}$ .  $F$  is then called a ‘crisp subset’ of  $\mathcal{F}$  and is able to be formulated as an  $\alpha$ -level cut of  $F$  ( $F_\alpha$ ) containing all the elements of  $\mathcal{F}$  that are compatible with  $A$  at least to the level  $\alpha$  (see Figure 5.1), i.e:

$$F_\alpha = \{w \in \mathcal{F} \mid \mu_F(w) \geq \alpha\} \quad (5.9)$$



**Figure 5.1;** Possibility function.

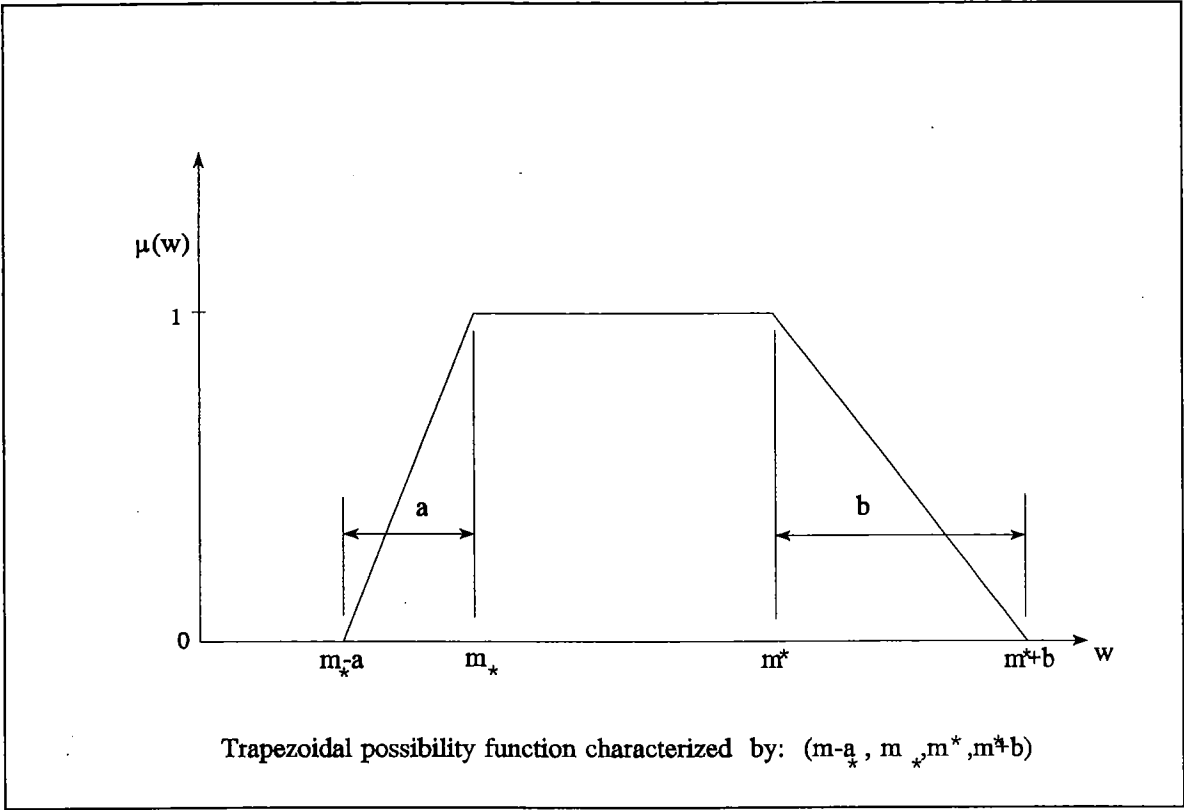
Often only the ‘core’ or ‘peak’ which is an  $\alpha$ -level cut at the level 1 and the ‘support’ which is an  $\alpha$ -level cut at the level 0 are defined. The core or peak is defined by:

$$C(F) = \{w \in \mathcal{F} \mid \mu_F(w) = 1\} \quad (5.10)$$

and the support is defined by:

$$S(F) = \{w \in \mathcal{F} \mid \mu_F(w) > 0\} \tag{5.11}$$

Trapezoidal representations of membership can also be defined (see Figure 5.2).



**Figure 5.2;** Trapezoidal possibility function.

Alternatively a fuzzy set can be considered to be a ‘trace’ of a possibility function. The trace gives a measure of the possibility of the truth of each event making up  $\mathcal{F}$ . The trace has a core for some  $w \in \mathcal{F}$ , where  $\pi(w) = 1$ . This is the sure event that  $\Pi(\{F\})$  focuses on but which can only be defined imprecisely. The uncertainty of each event is considered and the resulting trace allows an appreciation of the precision of the concept.

### 5.4.2 Information quadruple.

Dubois and Prade characterise a statement of information as a quadruple (attribute, object, value, confidence). An object is what the information refers to. The attribute is the domain quality from which a value is defined, e.g. length, mass, period. The value can be precise or imprecise. Confidence refers to the truth of the value given of the attribute about the object. Ambiguity enters when it is questionable whether the attribute belongs to the object and/or whether the object exists.

The use of possibility theory enables all uncertainty except ambiguity to be

considered. This means that mythical and ideological statements require to be decomposed into coherent metaphors or unmasked respectively as they involve the use of metaphor in an ambiguous way. Fuzzy statements that result from decomposition of mythical metaphors are able to be expressions of wisdom even though ambiguity has been overcome. However in doing so the wisdom is context specific. To unmask ideological statements the context is similarly significant as it serves to reveal what is being denied in the context and hence the incoherence and need for restructuring for coherence in the specific context. A wise set of statements may be ideological if used out of context.

**5.5 LOGIC AND DIALECTICS**

Ravetz (1990) and Funtowicz & Ravetz (1990) have developed a typology of the quality of numeration. This includes the precision and uncertainty clarified by Dubois and Prade in the first four terms below and another aspect termed ‘pedigree’:

- 1. Numeral
- 2. Unit
- 3. Spread
- 4. Assessment
- 5. Pedigree

The numeral refers to the basic symbol used to define the numeration. This can be numbers or it can be some other category. The unit along with the numeral define unambiguously what the significant figures of the numeration is. For example 56:E4 makes unambiguous what is unclear in the number 560000. The spread refers to the imprecision. The numeral, unit and spread together are what Dubois and Prade classify as the value. The assessment is an attempt to scope all the possible extensions of spread. Therefore it is an attempt to include systemic or non-parametric error into numeration (see Chapter 4). For example the spread may be able to be defined by a standard error or some other statistical means. However the assessment has to consider the different answers gained by different possible analyses, including strange outliers. The pedigree qualification refers to the means of obtaining and the socially granted significance of the numeration. For example, whether standard instrumentation is used in scientific method, or whether it is expert judgement obtained through dialogue. Pedigree refers to the social construction of numeration. So it is not an absolute criterion, but attempts to clarify what the meta-values are that are used to legitimize what is defined to be the truth in numerated knowledge. There are two aspects to this: the *success* of the numeration and its *pertinence*. Both of these two aspects are dependent on the context in which the

numeration is used. Success is an indication of the working of the model to fulfil its goal. Pertinence is an indication of the value of the goal to fulfil a social function. This approach can be interpreted as a development of radical constructivism's pragmatism (see Chapter 4).

There is a dialectical relationship between assessment and pedigree as well as between assessment and spread. For example, the pedigree of subjective probability is 'educated guesses'. But the assessment is usually given by a single probability value. This is the case because the domain of possible events is partitioned so that the normalising of the 'guessed' probabilities can be carried out. The spread may include various subjective guesses. If a possibilistic assessment was carried out then the pedigree could be based rather on objective statistics and synthesis of several experts' judgements. This adoption of belief values to synthesise possibility functions rather than subjective probability gives a far less precise result. The assessment is less precise but the spread may well be defined by the one possibility function through aggregation that is possible with possibility functions (see Chapters 7 and 9). Also the quality of the pedigree increases.

Ravetz adds to his development of the qualities of numeration, a theory about the dialectical interaction between ignorance and knowledge. The two dialectics outlined above can be interpreted as examples. Ravetz can be seen to agree with Luhmann (1974) that more complexity, uncertainty or ignorance occur as more instrumental values are sought. Therefore there is a dialectical relationship, between 'usable knowledge' and 'usable ignorance'. It means that seeking instrumental values (usefulness) inevitably produces ignorance (disinformation) as well as knowledge. According to Ravetz an inevitable tradeoff occurs somewhere where more knowledge about how to use things produces more problems than improvement. It is the situation Wilden (1980) comments on where there is a need for second-order feedback to limit and change instrumental values that are being sought due to a particular structure so as to produce meta-morphosis (see Chapter 4). Because of this, Ravetz (1990) also criticises naturalistic and/or rationalistic epistemologies to legitimize scientific method.

However if pedigree is considered in terms of success and pertinence the paradox can be avoided because second order feedback can be incorporated. If truth of knowledge includes its success and pertinence, ignorance will not be produced even by the application of scientific method because it will be legitimized through its functional coherence in explicit social construction.

### 5.5.1 The logical dialectic of the reflexive spheres.

The dialectic between knowledge and ignorance can be considered to occur within the reflexive spheres (see Chapter 4). If numeration is not successful then sphere 1 analysis will not produce the functional integration required for sphere 2 to be maintained and so sphere 3 causing reassessment of the modelling occurs which makes the pedigree low. Also if the numeration is not pertinent it means that goals aimed to produce functional integration in sphere 2 are dysfunctional, and once again sphere 3 is operational and the pedigree of the numeration becomes low. Statements (including numeration) that produce this systemic reflexive negation are what are labelled 'true and false'.

In contrast to Ravetz, a reflexive feedback in a co-evolving process is seen rather than a tradeoff. Instead of determining a tradeoff to limit knowledge acquisition, what is required is institution of monitoring to ensure that the social system is reflexive so that it has the flexibility to adapt. The explicit definition of success and pertinence are how this can be formalized into numeration so as to guide how analysis is carried out effectively to achieve this. What is required is a refocussing of the search for knowledge so that it remains always useful. This is necessary because there is a dialectic between pertinence and success. Greater pertinence in goals requires information and hence success in modelling. But there are inherent limits to the success of any particular model. Therefore there is always the need to seek ways to obtain monitoring to obtain information so as to increase overall pertinence while keeping a high success in each model as well. To achieve this, those who are modelling need to be reflexive: the inherent systemic reflexivity which leads to the rise and fall in pertinence of analyses (the existence of a trace of significance) has to be individuated (see Chapter 4).

Individuation of reflexivity involves thinking including the use of formal logic. It is the logic of self-referential systems. Gaines and Shaw (1987) reviewed how a definition of systems with comprehension of perception as its basis (like those which give rise to SUL) results in a self-referential system. It is the same conclusion that Nietzsche came to and which is what the reflexive spheres imagery developed attempts to model (see Chapter 4). That the systemic reflexivity is equivalent logically to Wilden's (1980) view of first and second-order feedbacks is consistent with him also defining systems the way Gaines and Shaw (1987) have. Brown's (1969) theory of forms develops this formally. Varela (1975) has shown that the self-referential system occurring based on Brown's formal theory is an infinite recursion. It means that perception without an absolute to frame it leads to re-perception that may be different. This is the process that co-evolution is based upon. It is also the state of perpetual openness and is what is termed spirituality

(see Chapter 3). Statements which are self-referential in this way are termed 'not true and not false'. They are an expression of meditation which ontologically opens up to the sacred and so the systems which are reconstructed are potentially contingently coherent and responding to second-order feedback. The reconstructions that arise are potentially adaptive because the openness to others perceives all ends and so functional integration can be sought with clarity. Therefore pertinence of analysis is also able to be achieved. But it is always contingent. For each recursive moment, which can be interpreted as a co-evolutionary moment, a pertinent reconstruction using metaphors can be carried out. For success as well as pertinence however, the reconstruction has to acknowledge vagueness and hence limits to success. Equally, because success and pertinence is maintained (to the extent that it can) disinformation does not arise as the creation of knowledge is limited. Therefore the occurrence of revolution rather than evolution may be avoided (see Chapter 4).

From a perspective which is not co-evolutionary, self-referential systems are only paradoxical and meaningless - the conclusion expressed in Bochvar's logic (see Table 5.2 above). Unless the distinction between 'true and false' and 'not true nor not false' can be made, which Bochvar does not do, there can be no logical basis for contingent reconstruction. The deconstructive school of postmodernism will merely carry out genealogical analysis to deconstruct history in failure to see the 'not true nor not false', and when the context is not appreciated it is interpreted as meaningless games (e.g. Hofstadter 1979).

For reconstruction the social and ecological functionality of the rationality developed from fundamental distinctions has to be explicitly recognized and used as a basis for legitimization. The lack of functionality is what has to be interpreted as second-order feedback. In other words a meta-organismic metaphor is required to legitimize the basic distinctions that the self-referentiality forever recreate within the recursive process. Analysis of the social and ecological functionality is the way to appreciate the life of the immortal gods directing the graceful growth of mortals, and is how systemic reflexivity can be individuated so wisdom is expressed (incarnated as Christ in their growth) by those thinking (see Chapter 3 and 4). Wisdom is expressed because there is awareness that one does not know about the indeterminate future; there is not arrogance about what is the most pertinent social reconstruction. Methodologically this involves monitoring to allow morphogenesis (see Chapter 4).

Because any particular reconstruction is contingent and subject to monitoring to change it there is no correct paradigm, but anarchic nihilism is avoided because social

construction in response to the awareness of the sacredness of the intrinsic value of potential growth in ethical relations always allows a normative direction to be perceived. Paradigm revolutions are also avoided because the degree of success and pertinence is explicitly appreciated and so re-evaluation occurs continually because social construction is explicitly appreciated (Kuhn 1970). Thus the traces of concepts and particular reconstructions can be expected to be gradual. However the analogy with punctuated equilibrium associated with co-evolution in ecology would suggest that relative stability of pertinence and knowledge forms can be expected, with gradual but relatively rapid change to new states in between these. Wittgenstein (see Outhwaite 1987) terms the traces of significant relations between concepts as 'family relationships'. Overall continuity occurs but also continual change.

As mentioned in Chapters 3 and 4, as far as ideas are concerned, postmodern views make a return to Plato prior to Aristotelian thought. This is so much so that Whitehead (1929) even talked of 'immortal objects' to refer to the integrative principles giving rise to hierarchical structure and the logic of co-evolution. This enables an explicit recognition of 'not true nor not false' because Platonic ideal types are both normative as well as descriptive. Hence they can serve as metaphors to help define meta-values associated with pertinence. What Platonic logic allows is the participation of entities within other entities to produce the interbeing relationship (see Chapter 3). This can serve as a metaphor for the perception of the sacred. Explicit links between the process (co-evolution) and the sacred is made (e.g. Sherburne 1966 and McDaniel 1986). The postmodern social constructionism developed here is different to this tradition however because the Platonic view is only taken metaphorically rather than rationalistically. But because logic is about formalization of abstract thought it is appropriate for the formulation of logic.

## **5.6 A LOGIC FOR RECURSIVE RECONSTRUCTION**

A review to develop the mathematics of MVLs to give general form to the rationalities involved in carrying out social reconstruction of knowledge within a co-evolutionary process is necessary. A rigorous development of postmodern modelling which considers the way success and pertinence are able to be incorporated into modelling so as to appreciate the context is required.

### **5.6.1 Success**

Success is concerned with how well a model accords with the achievement of a goal. Because both the output of a model and a goal are pieces of information they are defined according to the information quadruple defined by Dubois and Prade (1988). Also because they refer to the same thing, both the attributes and objects are the same. What can differ however are the values (including precision) and confidences (truth). Therefore success is a comparison of two values and two confidences; or two precisions and two certainties. These can be given a formulation in terms of a possibility function which reveals a dialectic between certainty and precision or value and confidence. To appreciate this it is necessary to first consider the different measures of confidence and how they can be obtained.

#### **5.6.1.1 Success as a possibility measure.**

Confidence as a possibility measure can be constructed by collating subjectively constructed illustrations of them (Dubois and Prade 1988). This is appropriate when information has vague or imprecise attributes and can be expected to be because of the way many goals are defined. It is an area where computer graphics and GIS with vague values could be expected to play an important role (see Chapters 9 and 10).

Confidence as a possibility measure can also be obtained as output from a model that is based on a causal metaphor and standard calculus carrying out a phenomenological analysis. Parametric imprecision can be explicitly included as a possibility trace of the parameter value or as a fuzzy set. An example is hydraulic modelling for floodplain management (see Chapter 7). Inclusion of the fuzzy parameters results in a possibility function or fuzzy output. The possibility trace of the parameter values can be obtained subjectively as mentioned above, or through the use of statistical sampling (see below in Section 5.6.1.2).

The goals which modelled output are compared with occur in two ways. Firstly as data, which enables determination of how *successful* the model is. Secondly as a functional goal which the model is being used to help achieve.

#### **5.6.1.2 Success as a probability value.**

Ravetz (1990) allowed the use of probability. In light of the above discussions however this would only be appropriate when the objects were separate (attributes are precise) and the process was being modelled with a random generator metaphor. The precision of the attribute should not be confused with the possible fuzziness of the value.



### 5.6.1.3 The use of success values.

The type of confidence measure is not independent of the other aspects of information. This is significant because a measure of confidence used as part of information in relation to subjective assessment is probability. This 'subjective probability' has been a mathematical technique widely used to give analysis of confidence where statistical data are missing (Dubois and Prade 1988). It has even been encouraged for use in floodplain management (Young 1990). Such situations fall between the two categories of using probability or possibilistic mathematics. Because such events (e.g. a flood) are appropriately modelled by a random generator metaphor, probabilistic confidence is appropriate. However the subjective nature and often collective process of the assessment puts it into the realm of possibilistic mathematics. A solution is to express fuzzy values of probability as used for example by Ishizuka et al. (1982), which mathematically are possibility functions of a trace of probability. This is difficult to reconcile however with the creation of probability density functions (pdfs). To clarify why requires a consideration of what a pdf is.

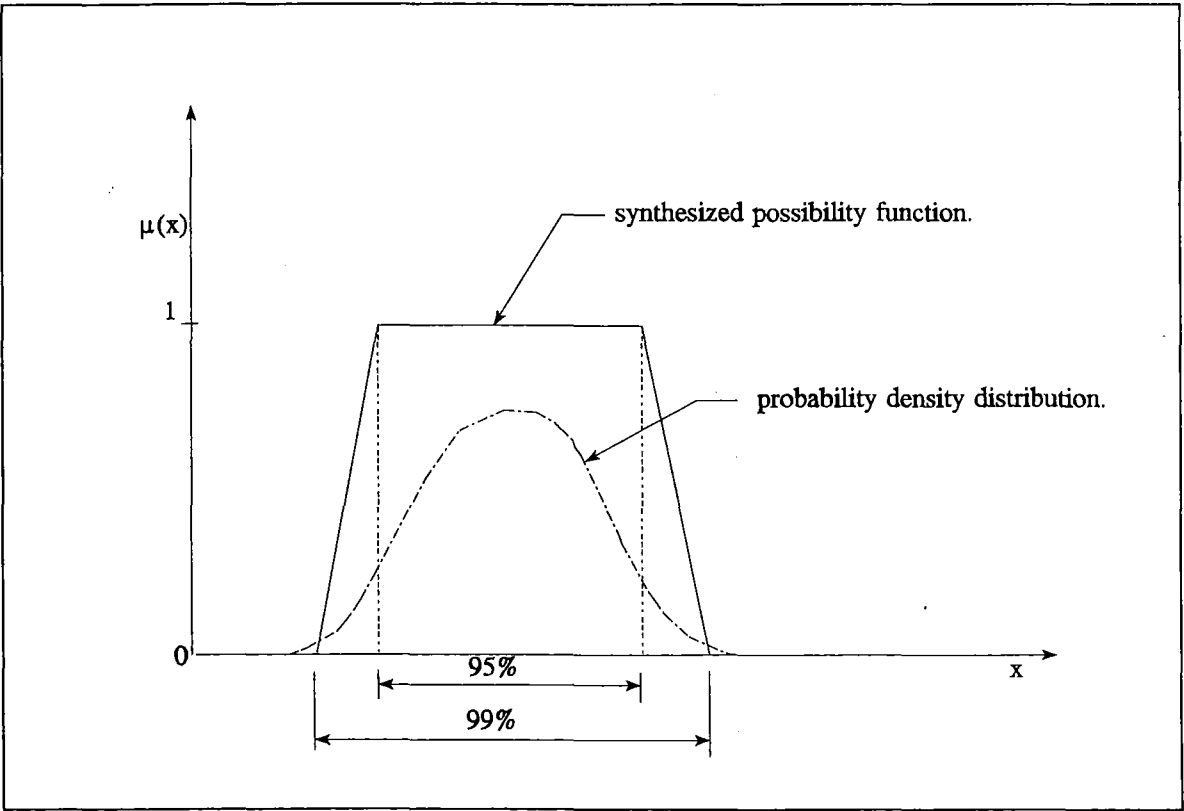
A pdf is a function obtained using standard calculus that describes the limit case as discrete independent singletons tend to become infinitesimal and so the domain is continuous. Therefore it is the use of an image used in standard calculus where the causal metaphor is used precisely and applied to describe situations where a random generator metaphor is used. Therefore in a pdf fuzzy probability of each singleton ceases to have meaning. The fuzziness in a pdf is not referring to confidence about the individual singletons but rather about the parameters used to describe the pdf image of them. However, practically the determination of fuzziness of parameters of a pdf is easy to obtain. Statistical techniques to determine parameter values based on sampling give a measure of confidence. The task is to transform the confidence measures obtained from statistical sampling into a possibility trace. Such an approach has been developed for use in risk analysis (see Chapter 6) and hydrology (see Chapter 7).

The fuzzy values obtained can then be used as part of a standard calculus model, using a causal metaphor whose values are fuzzified, which constructs the image of the pdf. The result is a fuzzy pdf according to exactly the same mathematics for modelling of a situation that uses a causal metaphor. What are used in such a model are standard calculus functions between fuzzy rather than precise values. Instead of the use of the equivalence relation in binary logic, a MVL equivalence comparing calculated (modelled) value and the goal is carried out. The comparison is a measure of success. It can have an intermediate value which is not possible when binary equivalence is used. This is why

rationalistic approaches which focus on the use of standard calculus mathematics and a precise causal metaphor (e.g Popper 1958), and are logically required to expect there to be one true answer, do not have a notion of success. The truth is considered to stand on its own irrespective of context.

To the extent that statistical sampling gives information the use of probability theory enables confidence levels to be obtained which can serve as the basis for a possibility trace. Box (1980) has argued that this approach should be used to define belief functions which are what Dubois and Prade (1988) call plausibility (which if monotonic gives possibility). However Box also argued that to increase the precision of the values subjective probability should be obtained through the use of Bayesian theory which updates subjectively determined values as more information is obtained. Philosophically it is equivalent to Popper's critical rationalism. The legitimacy of the use of Bayesian techniques is doubtful, in light of the arguments so far against critical rationalism, and so an alternative is suggested. The confidence values obtained through statistical sampling are subjectively interpreted to give a possibility trace of the probability value of the parameter which is equivalent to a fuzzy value for the parameter.

It can be termed an intuitive approach based on interpretation of statistical



**Figure 5.3;** Possibility function synthesis from a pdf.

confidence levels. Because an intuitionist philosophy of mathematics is also upheld this is considered to be appropriate. There is no claim that it is anything other than a helpful social construction that may serve a pragmatic end. The core is intuitively considered to be given by the 95% range and the support by the 99% range (see Figure 5.3). If it can be assumed that the sampling gives rise to a normal distribution then these values can be directly obtained from measurement of variance which is also used in the determination of the parameters themselves and so the technique is straightforward. This is carried out for hydrological analysis in Chapter 7. It allows for synthesis of fuzzy pdfs and cumulative density functions (cdfs).

#### **5.6.1.4 Sensitivity analysis and the Central Limit theorem.**

There are other issues which arise from the modelling of situations according to a random generator. Two important ones are: to what extent is the Central Limit theorem implemented, and how such approaches compare to the use of sensitivity analyses. Once again it is a matter of matching the appropriate mathematics to the appropriate modelled situation. Because of the lack of knowledge about possibilistic mathematics and MVLs other than probabilistic logic, the Central Limit theorem and sensitivity analysis have been used when they have been inappropriate because no other tools have been available.

The Central limit theorem allows for the relative decrease in spread where more than one identical random distribution is included in standard calculus mathematical analysis involving pdfs. Such situations occur where an identical random generator metaphor is applied to different situations. An example is the expected sum in a period of flood damage due to floods (see Chapter 7). However it cannot be applied when sampling is not modelled as occurring from the same distribution; e.g. uncertainty about the value of different parameters obtained from occurrence of floods, flood magnitude and damage for a given flood. They are all different distributions. Such uncertainties require instead possibilistic analysis through the fuzzification of values as developed above.

Sensitivity analysis claims to carry out the determination of overall systemic uncertainty but without the process of fuzzification of parameters and production of a possibilistic output. The similarity is that if sensitivity analysis had all its parameters randomly sampled according to the distributions they each produce and was modelled by a Monte Carlo simulation, then the output would be equivalent to a possibilistic analysis involving the intuitive creation of a possibility trace out of a statistical distribution mentioned above. The difference is that a possibilistic analysis is easier to do!

In sensitivity analysis only one parameter is shifted at a time so as to observe the

outputs. All that is being done is to see whether the calculated average (as a phenomenological analysis) can be taken to be precise or not. No measure of its precision or success is able to be made. If a measure of success or confidence in the output is required then a Monte Carlo simulation is required. All that can usually be carried out through a sensitivity analysis is a subjective decision about whether the output is too sensitive for it to be accepted as a precise result. In other words the situation analogous to Popper's rationalism arises again. Binary logic is used to decide to accept or reject the model. Only if a very precise result occurs because all significant parameters are very precise is sensitivity analysis appropriate. But because this cannot be known before it is carried out there is no advantage in not carrying out a possibilistic analysis which is as straightforward as a sensitivity analysis, without the need for a Monte Carlo simulation.

### 5.6.1.5 Standard calculus with fuzzy values.

A continuous isotonic function,  $f$ , with for example two variables,  $M$  and  $N$  that are fuzzy is given by (see Figure 5.1):

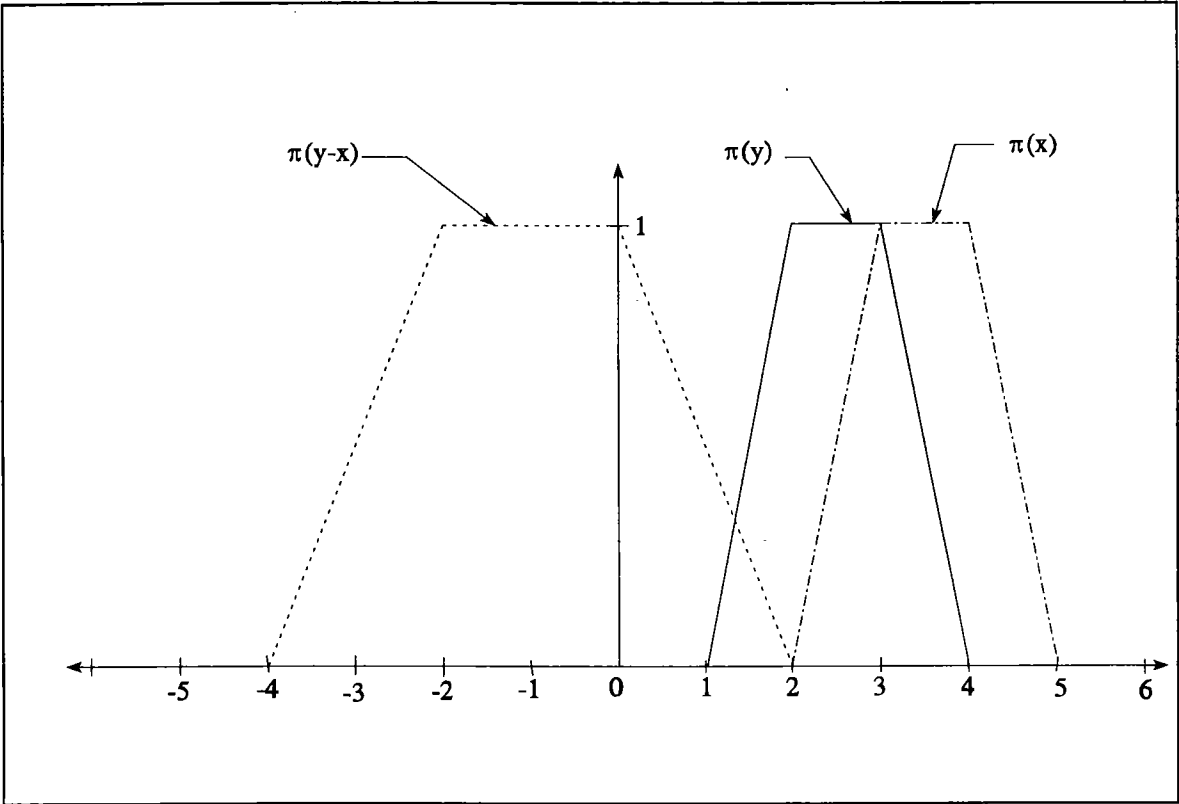
$$\forall \alpha \in ]0,1], f(M_{\alpha},N_{\alpha}) = [f(m_{*\alpha},n_{*\alpha}), f(m^*_{\alpha},n^*_{\alpha})] \quad (5.12)$$

Thus calculation of fuzzy standard calculus is straightforward if the function is continuous and isotonic. It simply requires calculation of particular upper and lower  $\alpha$ -level cut values. If the variables are trapezoidal then it involves four calculations of:  $m_{*-a}$ ,  $m_*$ ,  $m^*$ ,  $m^*+b$ ; each as if the analysis is precise (see Figure 5.2). If however the function is not isotonic then the function has to be transformed. If not continuous it has to be considered in a piece-wise fashion. The transformation of continuous functions to be isotonic is fortunately straightforward. A function  $f$  with a quantity  $x$ , has to be transformed to be isotonic (i.e. either addition or multiplication) by transforming the variable into  $u(x)$ . This is always possible but may require extensive nesting. It is applied in Chapters 6,7,8 and 9. The possibility values  $\mu_{f(x)}(u)$  for each particular transformation involved in calculations carried out in following chapters are given in Table 5.5.

$f(u)$	$\mu_{f(x)}(u)$
$-u$	$\mu_x(-u)$
$1/u$	$\mu_x(1/u), u \neq 0$

**Table 5.5;** Transformations for isotonicity.

These transformations are only possible if the support given has  $x > 0$  or the support of  $x < 0$ . It cannot straddle the origin. This has consequences especially for fuzzy numerical methods (see Chapter 9).



**Figure 5.4;** Fuzzy arithmetic.

For example consider:  $f(x,y) = y-x$   
 where  $\pi(y) = (1,2,3,4)$  and  $\pi(x) = (2,3,4,5)$   
 let  $u=-x$   
 $\Rightarrow f(u(x),y) = y+u(x)$   
 and hence  $\mu_{u(x)}(u) = \mu_x(-u)$   
 $\Rightarrow \pi(u) = (-5,-4,-3,-2)$   
 and from Equation 5.12  $\pi(f(x,y)) = (-4,-2,0,2)$  (see Figure 5.4).

**5.6.1.6 Determination of success.**

Once possibility functions expressing fuzzy output from situations, which are modelled by either a random generator metaphor or a causal metaphor are obtained, fuzzy goals and a measure of success can be formally obtained. The dialectical relationship between precision and certainty becomes clarified also.

If A and F are the goal and modelled output respectively, a compatibility function,

$CP(F;A)$ , has been developed which defines a relation between the truth values of the modelled output and how successfully they achieve the goal (Dubois and Prade 1988). Thus the compatibility function is a possibility trace or truth weighting over the possibility trace of the fuzzy set describing the goal, given the modelled output. The truth values for the compatibility function are given by Equation 5.13.

$$\begin{aligned} \mu_{CP(F;A)}(v) &= \sup_{s, v=\mu_F(s)} \mu_A(s) \\ &= 0 \quad \text{if } \mu_F^{-1}(v) = \emptyset \end{aligned} \quad (5.13)$$

This makes it clear how success of the modelling is a truth or confidence valuing on top of the truth or confidence of the conclusion from the model. The measures of success from the compatibility function can also be given in terms of possibility and necessity measures (Dubois and Prade 1988):

$$\Pi(F; A) = \sup_{v \in [0,1]} \min(v, \mu_{CP(F;A)}(v)) \quad (5.14)$$

$$N(F; A) = \inf_{v \in [0,1]} \max(v, 1 - \mu_{CP(F;A)}(v)) \quad (5.15)$$

Equations 5.14 and 5.15 have been simplified by Dubois and Prade to avoid the need to use the compatibility function:

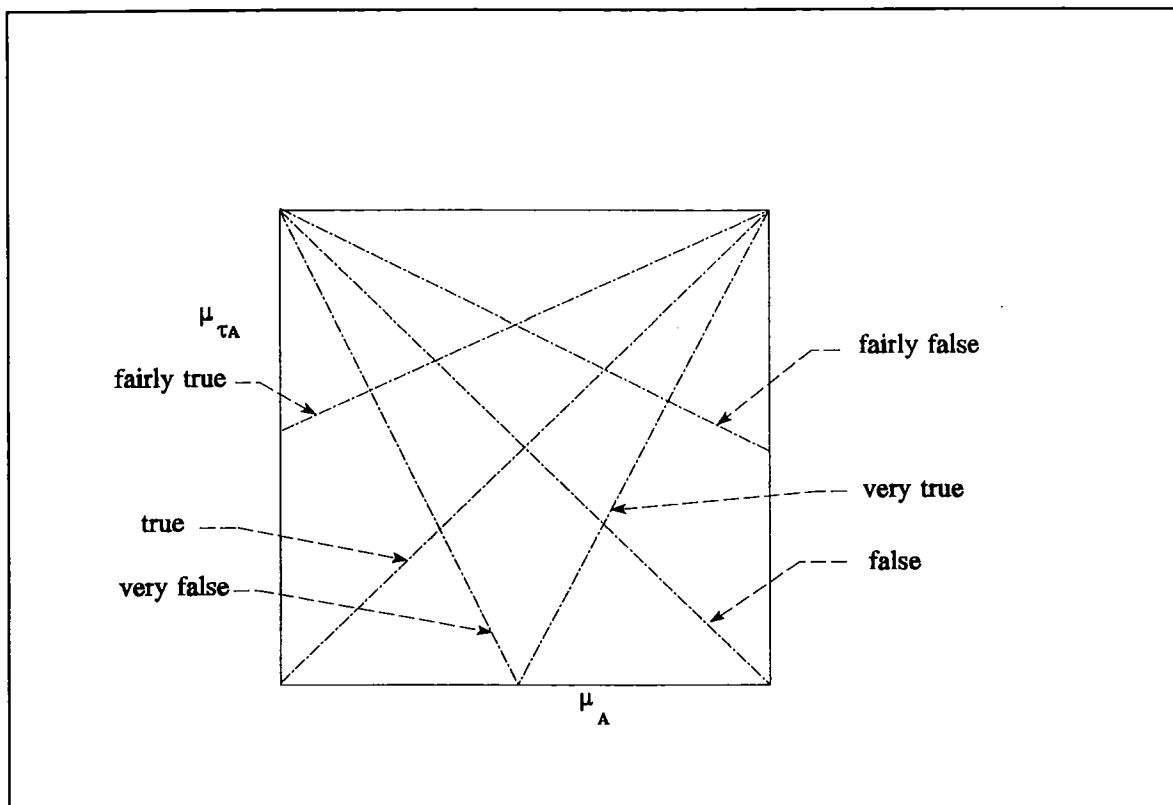
$$\Pi(F; A) = \sup_{s \in S} \min(\mu_F(s), \mu_A(s)) \quad (5.16)$$

$$N(F; A) = \inf_{s \in S} \max(\mu_F(s), 1 - \mu_A(s)) \quad (5.17)$$

Application of the compatibility function for hydrological modelling is given in Chapter 7.

#### 5.6.1.7 Dialectical relation between precision and certainty.

Baldwin (1981) used the compatibility function to explore the dialectical relationship between precision and truth (certainty), but without making it explicit. He merely used the property. What he did was develop a method that incorporated the truth weighting given by the compatibility function (success - not his term) into the conclusion from the model. Thus he implicitly defined a dialectical relationship. A success measure was considered to always be present in definition of a conclusion. Also a standard success is implicitly defined and considered to occur when the value and confidence of the output remains unaffected by evaluation of its success. Any deviation from this standard



**Figure 5.5;** Truth weightings for linguistic statements.

success, either more affirmative or otherwise, results in a transformation of the model's conclusion if standard success is to be kept. Baldwin as reviewed by Blockley (1980) represented this graphically (see Figure 5.5). The success value (not a term Baldwin or Blockley used) was considered to be a truth restriction weighting represented by the symbol  $\tau$ .

#### 5.6.1.7.1 Truth functional modification.

Baldwin used terms already introduced by Zadeh in earliest development of Fuzzy Set theory, that of Truth Functional Modification (TFM) and Inverse Truth Functional Modification (ITFM) to describe the dialectical interaction. TFM involves transforming fuzzy propositions which have an explicit success value evaluated into one where the fuzzy membership values of the fuzzy set (or possibility function) are given by success values for the fuzzy membership values. The transformations of Equations 5.14 and 5.15 into Equations 5.16 and 5.17 are examples. It is termed truth functional modification because the effect is to change the truth tables relating the proposition to others.

The process can proceed the other way also to statements which have been effectively transformed to have a standard success to one where a success value evaluation

is explicitly added in the definition of the fuzzy set memberships.

Blockley also developed from Baldwin's work how the success value can be used linguistically. Thus equivalent linguistic statements can be formed due to the dialectical relationship. The relations can be obtained from definition of linguistic statements by a fuzzy set membership with Figure 5.5, and the use of TFM and ITFM.

A limitation with Blockley's and Baldwin's use of the compatibility function and the dialectical relationship resulting is that the comparison and equivalences between linguistic statements can only occur between propositions which have the same core (see Section 5.6.2.2.2). To the extent that the core is different then imprecision is complete with no support being able to be defined. A way to avoid this is to consider fuzzy inequalities rather than fuzzy equivalence. This makes the modelling applicable to teleological analysis. Dubois and Prade (1988) have given an interpretation of four measures of inequality. They report that at that date no counter-intuitive rankings had occurred. For comparison between two fuzzy variables, X and Y are defined by:

1. The exceedance possibility  $\Pi(X^* \geq Y_*)$  which is the possibility that the largest values that X can take are at least as great as the smallest that Y can take.  $X^*, X_*, X^*, X_*$  are an expression of the notation used in Figures 5.2.

$$\Pi(X^* \geq Y_*) = \sup_{u \geq v} \min(\mu_X(u), \mu_Y(v)) \quad (5.18)$$

2. The strict exceedance possibility  $\Pi(X^* > Y^*)$  which is the possibility that the largest values that X can take are greater than the largest values that Y can take.

$$\Pi(X^* > Y^*) = \sup_u \inf_{v \geq u} \min(\mu_X(u), 1 - \mu_Y(v)) \quad (5.19)$$

3. The exceedance necessity  $N(X_* \geq Y_*)$  which is the necessity that the smallest values that X can take are at least equal to the smallest values that Y can take.

$$N(X_* \geq Y_*) = \inf_u \sup_{v \leq u} \max(1 - \mu_X(u), \mu_Y(v)) \quad (5.20)$$

4. Strict exceedance necessity  $N(X_* > Y^*)$  which is the necessity that the smallest values X can take are greater than values that Y can take.

$$N(X_* > Y^*) = 1 - \sup_{u \leq v} \min(\mu_X(u), \mu_Y(v)) \quad (5.21)$$

What is required is that the four indices be interpreted as values of success that can be given linguistic interpretation. The dialectical relationship given by TFM and ITFM is not



able to be incorporated. Instead of synthesizing linguistic equivalent statements, what can only be carried out is linguistic interpretation of the success of specific options in relation to a goal as carried out in teleological analysis. A possible interpretation is:

If  $\Pi(X^* > Y^*) < 1$  it is false that  $X > Y$ ,  
and if  $N(X^* > Y^*) = 0$  it is very false,  
and if  $\Pi(X^* > Y_*) = 0$  it is absolutely false.  
If  $\Pi(X^* > Y^*) = 1$  it is true that  $X > Y$ ,  
and if  $N(X^* > Y^*) = 1$  it is very true,  
and if  $N(X_* > Y^*) = 1$  it is absolutely true.

The use of the above analysis enables linguistic interpretation of different options to be made which can help in public discussion of results. An example is given in Chapter 9.

Often lowest or highest values are sought to be a goal for which comparison is made so as to determine a set of fuzzy maximum or minimum values. This can either be carried out by pairwise comparison of fuzzy sets using Equations 5.18 -5.21 or by definition of a global minimum or maximum synthesized from all fuzzy sets for which all are then compared. Dubois and Prade have developed what the global maximum,  $\max^*$ , and global minimum,  $\min^*$ , are for trapezoidal functions as defined in Figure 5.2. For comparison of  $k$  fuzzy sets representing a goal  $F$  the global maximum and global minimum fuzzy sets are given by the trapezoidal indices:

$$\Pi(\max^*(F)) = (\max_k(m_{*k} - a_k), \max_k(m_{*k}), \max_k(m^*_k), \max_k(m^*_k + b_k)) \quad (5.22)$$

$$\Pi(\min^*(F)) = (\min_k(m_{*k} - a_k), \min_k(m_{*k}), \min_k(m^*_k), \min_k(m^*_k + b_k)) \quad (5.23)$$

Evaluations of the highest and lowest in terms of the indices given by Equations 5.18-21 are obtained thus:

- (i)  $\Pi(F_k \geq \max^*(F)_*)$ ;  $\Pi(F_k \leq \min^*(F)_*)$
- (ii)  $\Pi(F_k > \max^*(F)^*)$ ;  $\Pi(F_k < \min^*(F)^*)$
- (iii)  $N(F_k \geq \max^*(F)_*)$ ;  $N(F_k \leq \min^*(F)_*)$
- (iv)  $N(F_k > \min^*(F)^*)$ ;  $N(F_k < \min^*(F)^*)$

### 5.6.2 Pertinence

Pertinence is concerned with the context in which the modelling is used. Attempts to obtain high values of this aspect of pedigree is an art because it involves creative reconstruction. The creative reconstruction of modelling is required to have an aim to

incorporate monitoring for deviance from the norm of flexibility achieved through seeking social justice and increasing biodiversity (see Chapters 3 and 4). Pertinence refers to whether or not the operations that are required to fulfil these functions are carried out or not. Thus it is a measure of the validity of an implication that relates an activity to the fulfilment of the required function. Thus it is a measure of the success in constructing a structure (algorithm) of logical operations that fulfil the overall goal. It is an art because there are any number of possible algorithms that could potentially be created in the attempt to achieve the overall goal.

The operationalization of the algorithm requires the use of information that is available; whether future information that is obtained through monitoring or already existing information. Imprecision and uncertainty of the information has to be taken into account in the logical operations involved and so MVLs are involved. There can be more than one source or datum from a particular source and so aggregation of the data is required. Possibility theory enables great flexibility in modelling aggregation principles. The various ways are reviewed in Chapter 9.

The use of logical operations for modelling has been formulated in various ways. Blockley reviewed how this can be carried out using TFM and ITFM from Baldwin. Dubois and Prade have given a more general review which incorporates the approach of Baldwin. They define a grammar involving facts and rules. There are two generic methods of inference which employs rules. One for precise facts and one for imprecise facts.

#### **5.6.2.1 Facts.**

Facts are able to be defined by linguistic statements defining the attribute and object. The value and confidence are given numerical values. The numerical values for confidence are representative of the linguistic qualifications, e.g. the necessity and possibility that the fact is true. The confidence includes the truth weighting of the success of the fact. Therefore a fact can be interpreted as referring to the degree of achievement of a sub-goal nested within a teleological analysis and hence part of a system modelled by an organismic metaphor. A fact has no meaning outside of its functionality. This is the meaning of pragmatic epistemology. Therefore there is a relationship between success and pertinence that is hierarchical. At any particular level of integration, values of pertinence are values of success at a higher level of integration. The modelling used to calculate data that are used to evaluate a success value can often use a causal metaphor (for hydrological examples see Chapter 7), or is itself a conclusion from a rule.

When the fact is precise the two qualifications of possibility and necessity can be represented by two numbers respectively and normalized:

$$b, b' : b \leq b' \text{ and } b=0 \text{ or } b'=1$$

The normalization is carried out so that either it is held that the fact is mainly satisfied (possibility  $b'=1$ ) or that it is mainly not satisfied (necessity  $b=0$ ). When the fact is fuzzy then the value is represented by a possibility function.

The effect of the truth weighting of its success allows TFM and ITFM to produce equivalent statements with the same core, for fuzzy use of the causal metaphor. Or if specific options are evaluated, success enables comparison between them to rank options involved in a teleological analysis nested within an organismic metaphor.

An imprecise fact can also be described by the two numbers  $b$  and  $b'$  in the same way as a precise fact through using the special cases of the compatibility function giving possibility and necessity values (see Equations 5.16 and 5.17). There is no certainty of these being normalised. To do so Dubois and Prade have suggested the use of Equation 5.24 and 5.25 below where  $b^*$  and  $b'^*$  are the normalised values of  $b$  and  $b'$  respectively.

$$b^* = 1 - \frac{1-b}{\max(1-b, b')} \quad (5.24)$$

$$b'^* = \frac{b'}{\max(1-b, b')} \quad (5.25)$$

Or if the fact is the conclusion of a subgoal that has been modelled normalisation of  $\Pi(F;A)$  and  $N(F;A)$  to give  $\Pi^*(F;A)$  and  $N^*(F;A)$  so that  $\max(\Pi^*(F;A), 1-N^*(F;A)) = 1$  is given by:

$$\Pi^*(F;A) = \frac{\Pi(F;A)}{\max(1-N(F;A), \Pi(F;A))} \quad (5.26)$$

$$N^*(F;A) = \frac{1-N(F;A)}{\max(1-N(F;A), \Pi(F;A))} \quad (5.27)$$

Transforming information in this way enables the integration of fuzzy and precise facts in logical statements.

### 5.6.2.2 Inference rules.

The use of rules which are uncertain is termed approximate reasoning by Dubois and Prade (1988). However there are two types of rules. One type occurs where the

premises (facts) are precise and the other when the premises are fuzzy. For avoidance of ambiguity the term approximate reasoning is used here to refer to rules involving precise premises, and the term fuzzy logic to refer to rules involving imprecise premises. Both approximate reasoning and fuzzy logic involve uncertainty.

**5.6.2.2.1 Precise premises: approximate reasoning.**

When the premises are precise then the confidence of the implication between say p and q is qualified by the sufficiency and necessity that the conclusion holds. These qualifications are given numerical values, say (a,a') as to the confidence respectively that:

$$N(p \rightarrow q)$$

$$N(q \rightarrow p)$$

So with a precise premise (fact) an inference can be deduced (Dubois and Prade 1988):

$$N(p \rightarrow q) \geq a$$

$$N(q \rightarrow p) \geq a'$$

$$\underline{N(p) \geq b; \Pi(p) \leq b' \text{ with } \max(1-b, b') = 1}$$

$$N(q) \geq \min(a, b), \quad \Pi(q) \leq \max(1-a', b')$$

The result is a conclusion defined by a couple of normalised numbers and so can be used as a fact in further approximate reasoning rules. Note that instead of exact numbers inequalities are used. This is reasonable when considering Equations 5.14 and 5.15 where  $\Pi(F;A)$  is given by the supremum of a set of values and  $N(F;A)$  is given by an infimum of a set of values.

**5.6.2.2.2 Imprecise premises: fuzzy logic.**

Using imprecise premises in rules is what Zadeh, Baldwin and Blockley have termed fuzzy logic. In fuzzy logic the propositions are imprecise as well as being of uncertain truth (success as sub-goals). A proposition p is of the form p = "X is A" where A is a fuzzy set on a reference set say S. For example a multi-valued modus ponens inference "if p then q, and given p therefore q":

$$\begin{array}{l} p \rightarrow q \\ \underline{p} \\ q \end{array}$$

in fuzzy logic is given by:

$$\begin{array}{l} X \text{ is } A \rightarrow Y \text{ is } B \\ \underline{X \text{ is } A'} \\ Y \text{ is } B' \end{array}$$

where  $q = "Y \text{ is } B"$ , and  $"Y \text{ is } B"$ ,  $"X \text{ is } A"$  and  $"Y \text{ is } B"$  are all fuzzy sets on the same reference set  $S$ .

$$\forall t \in T, \quad \mu_{B'}(t) = \sup_{s \in S} ((\mu_A(s) \rightarrow \mu_B(t)) \wedge \mu_{A'}(s)) \quad (5.28)$$

What the conjunction operator and implication operator are depends on what MVL is used.

Zadeh suggested the use of Lukasiewicz' axioms and this was taken up by both Baldwin and Blockley. However Dubois and Prade prefer the use of Godel's axioms. As mentioned above it is not yet clear how pertinent such choices are, but a priori, both Lukasiewicz and Godel's axioms are appropriate depending on the context. It is therefore potentially a pertinent issue.

Baldwin and Blockley use a more complicated but mathematically equivalent version to Equation 5.28 which involves TFM and ITFM:

$$\mu_{CP(B;B')}(v) = \sup_{u \in \{0,1\}} (u \rightarrow v) \wedge \mu_{CP(A;A')}(u) \quad (5.29)$$

giving

$$\mu_{B'}(t) = \mu_{CP(B;B')}( \mu_B(t) ) \quad (5.30)$$

Evaluation of the success of an implication can be included also through using

$\tau = CP(A \rightarrow B; X \rightarrow Y)$  which gives:

$$\forall t \in T, \quad \mu_{B'}(t) = \sup_{s \in S} \mu_{\tau}((\mu_A(s) \rightarrow \mu_B(t)) \wedge \mu_{A'}(s)) \quad (5.31)$$

A significant result from (Dubois and Prade 1988) is that:

$$\forall A', \quad \mu_{B'}(t) \geq \sup_s (\mu_{A'}(s) \mid \mu_A(s) = 0)$$

The inequality means that there is a uniform degree of indetermination whenever a significant part of  $A'$  is not included in  $A$ . If there exists  $s \in S$ ,  $\mu_{A'}(s) = 1$  and  $\mu_A(s) = 0$  then  $B'$  is completely indeterminate. So if  $A'$  is different to  $A$  and not merely a different definition of precision then the generalised modus ponens is not adequate to deduce  $"Y \text{ is } B"$ . This result is an expression of why TFM and ITFM require the core of possibility functions or fuzzy sets to be the same if they are to be used to define equivalent statements. Further information is required to determine the causal relationship between a change in  $A$  and a change in  $B$  if this is not the case. Alternatively instead of attempting to make equivalence mappings fuzzy inequality definitions can be used. For example if premise  $X$  is the expected flood damage and premise  $Y$  is stopbank height then to deduce

the expected flood damage for a given change in stopbank height requires extra information as to what is the relationship between the expected flood damage and stopbank height as well the change in the stopbank height. To model this situation requires a list of premise-conclusion couplets, necessary also when using precise premises. If it was not MVL being used, but rather binary logic, the relationships could be described by precise differential equations. However because MVL is used the fuzzification of differential equations is one possible method. This is carried out for this problem in Chapter 8. Alternatively comparison of specific options can be carried out using fuzzy inequality. An example of this is given in Chapter 8.

If the propositions are linguistic statements which can have adjectives applied then for example the statement X is A' without an adjective can have its qualification by an adjective represented by a truth weighting through the TFM/ITFM dialectic or measure of success. However this only applies where a qualified statement is not sensibly different to the 'original'. For example, a highly catastrophic flood and a catastrophic flood may be sensibly different because they have different relations to hazard creation and hence social construction of risk (see Chapter 6). Thus they have different pertinent algorithms. Therefore different use of generalised modus ponens is inappropriate: different rules are required. In such situations the adjectival qualifications with the generic term do not represent a dialectical relationship. The basic rule of composition of algorithms is that linguistic statements need to be decomposed into statements which can be framed dialectically. Reconstruction can then occur. Thus success and pertinence are synthesized and the appropriate levels to make a pertinent algorithm are meshed together.

**5.6.2.2.2.1 Modus tollens.**

A type of deduction commonly used in binary logic along with modus ponens is modus tollens given by:

$$\begin{array}{l} p \rightarrow q \\ \text{---} \neg q \\ \text{---} \neg p \end{array}$$

The solution requires the equivalence between the rules "if p then q" and "if not p then not q". This is problematic when the premises are imprecise as some MVL fail to produce it. Dubois and Prade point out that Lukasiewicz' MVL enables this assumption to be made whereas Godel's does not. However when the assumption can be made then the generalized modus tollens is:

$$\frac{X \text{ is } A \quad \rightarrow \quad Y \text{ is } B}{X \text{ is not } B'} \\ Y \text{ is not } A'$$

$$\forall s \in S, \quad \mu_{A'}(s) = \sup_t (\mu_A(s) \rightarrow \mu_B(t)) \wedge \mu_{B'}(t) \quad (5.32)$$

### 5.6.2.2.3 Synthesis of precise and imprecise rules.

Imprecise facts can be changed into precise premises but not the other way around. Therefore the synthesis of approximate reasoning and fuzzy logic requires that the overall structure be that of approximate reasoning. But this need not happen when imprecision is present until a decisive conclusion obtained from a normalized approximate deduction is required. The art is to decompose all linguistic statements as mentioned above. Precise facts can be integrated into this logic by defining fuzzy sets where the support equals the core.

Such modelling can be carried out according to causal, random generator and/or organismic metaphors and so all possible non-technical and technical information can be synthesised as long as mythic knowledge is understood and used to guide creative use of the organismic metaphor and hence definition of the levels to be meshed together. When this is carried out pertinence can remain high. The context needs to be understood wisely.

## 5.7 CONCLUSION

The logic developed here enables general formal structuring of models according to the metaphors found to be necessary in the development of ethical and integrated understanding reviewed and developed in Chapters 3 and 4. Furthermore, the dimensions to the formal structuring have been clarified thus enabling appropriate models to be rigorously developed. Thus the first part of developing an integrated methodology has been constructed. Following chapters develop general structures that are found to be pertinent for floodplain management within these dimensions, and according to the general logical forms developed.

The process of developing the general structures within the logical dimensions and general form has been found to require creative artistic expression as well as empirical science; deduction as well as intuition. Even though this may not make it obviously any simpler than existing rational frameworks, it can however be expected to enable explicit synthesis of facts and values and all types of discourse without privileging any particular type of rationality. Therefore it can be expected to nurture and be nurtured by personal

relating involving dialogue and conversation free from ideological coercion. Thus it can be expected to help wise modelling be carried out.



# Risk Analysis

The literature on risk is very revealing of the social construction of risk analysis and hazards. From this, very strong arguments are found to radically alter the way risk is managed, and also to radically change the institutions risk management carried out for and within. This is because of fundamental incoherence in the dominant understanding of risk. Suggestions as to what changes are required so as to reconstruct a coherent approach are outlined.

## 6.1 INTRODUCTION

*Risk* is a term which is the product of a particular attitude and worldview. The worldview it is associated with does not rest solely on objective events. The term associated with objective events is *hazard*. *Risk* refers to the consequences of an action which has overall consequences that are acceptable, even if some can be detrimental. In contrast *hazard* refers to an objective event to be avoided. In floodplain management it is not immediately obvious whether the concern is or should be for an analysis of hazard or risk. At the very least, the distinction between what is a hazard and what is a situation of risk needs to be made. It is found that both are involved. It is found important not to confuse the two so as to engage in unreflexive social construction and participation in structural power relations of ideology. However both *hazard* and *risk* are equally socially constructed. Hazard by how the objective world is constructed, which is a consequence of interaction with the environment, and risk by what social relations are in place to make detrimental effects palatable.

If a situation of risk is considered a hazard then it is a type of scare-mongering and appropriately called irrational or ideological politicking. However the onus is on the risk analyst to provide a coherent worldview of why some possible detrimental events are necessarily part of life and so risk analysis is appropriate. Such an analysis based on the use of reciprocity and trust as well as more classical risk analysis is developed in this chapter. It is also required that the risk analyst provide a rigorous analysis of what the risk is. Methodology to do this is also developed in this chapter.

Alternatively a hazard can be labelled a risk. This is the more usual scenario in contemporary postmodern western society. It has been widely commented upon.

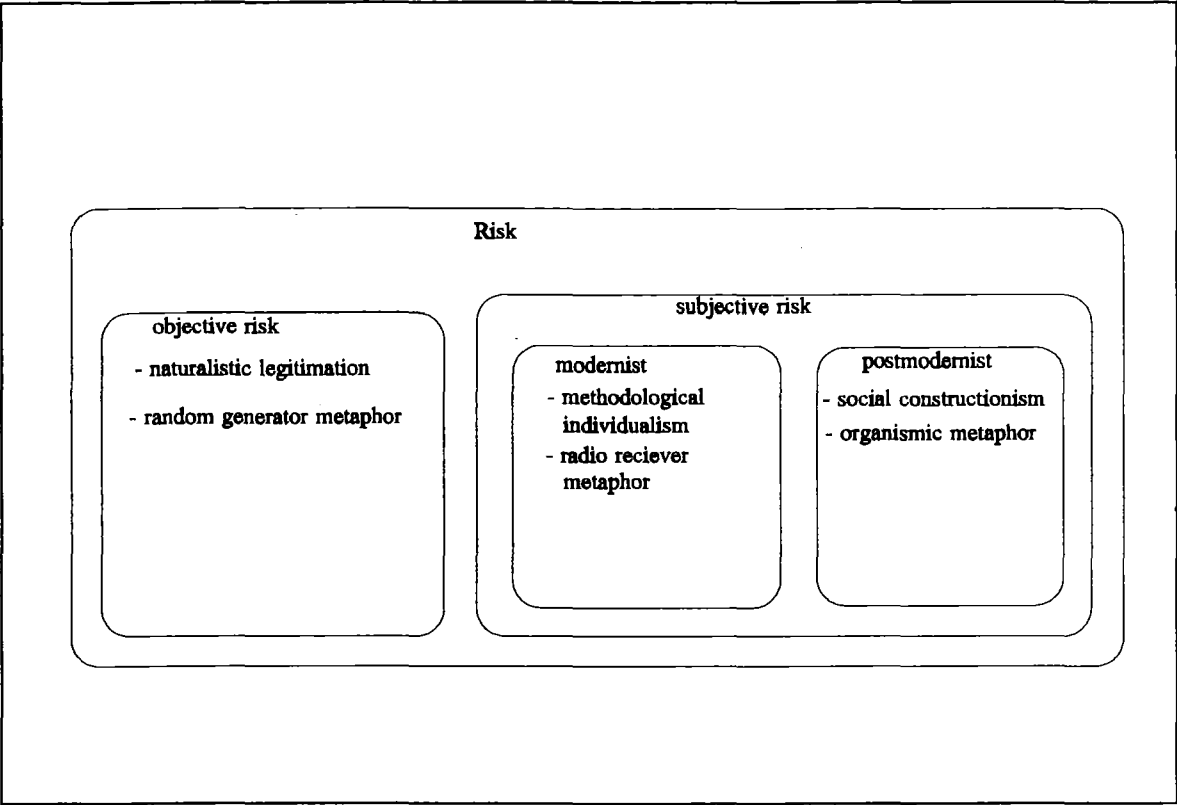
McLaughlin (1993), for example, reviews literature that indicated how framing a situation as one of risk puts the onus on environmentalists to argue against industrial development. More generally, it can be stated that framing situations of possible detrimental consequences as situations of risk biases the process of analysis toward continuation of existing activities. For example, the Ministry for the Environment analysis of Aotearoa/New Zealand's environmental situation (Ministry for the Environment 1994) talks only of risk associated with existing development and activities. The deeper questions of whether or not the fundamental bases for the worldviews and activities (including social structures) may need questioning and/or changing are not even acknowledged. The reason this is such an issue in contemporary postmodern western society is that relatively high levels of risk are a feature of the competitive market institution. Fromm (1942), in his seminal work, has been critical of the levels of risks instituted by the competitive market institution because of the anxiety that it has brought to members of society, especially for those on behalf of whom the risk decisions are made; i.e. those affected by the development in a detrimental way without a say as to what the development is/was going to be.

Therefore the issue of whether or not to frame an issue as one of *risk* or *hazard* introduces the further issue of social justice/social sustainability and hence ecological sustainability, as well as ethics in general.

The title of the chapter remains 'Risk Analysis', but in doing so a reflexive approach to make substantive distinctions between what is a situation of risk and what is a situation involving a hazard is carried out. Further a reflexive approach in relation to the social construction and legitimation of social activities is carried out so that the contextual appropriateness of different risk analyses is appreciated. In doing this, implicit ideological coercion by risk analysis is avoided and reconstruction of risk methodology based on the meta-values of sustainability is at least initiated.

## **6.2 THE PHILOSOPHY OF RISK**

Formal definitions of risk in the literature are many and varied (e.g. Gough 1988,1989,1990; and Pyle and Gough 1991). However an analysis of the underlying philosophical assumptions makes classification and meaningful critique straightforward. The broadest category distinguishes between objective and subjective risk. Then within the subjective risk branch there are two types; one from the modernist paradigm and the other from an emerging postmodern one (see Figure 6.1).



**Figure 6.1;** Typology of risk.

**6.2.1 Objective Risk.**

This is what has to also be called naive risk. It is what textbooks producing elementary ‘cookbook’ risk analysis teach and was the first to be developed. It emerged from engineering quality control studies. The general application of it has been due to the lack of discussion and reflexive consideration of methodology. For example it is how the Ministry for the Environment (1994) defined risk:

‘The product of *probability* times *impact*.’

(Italics are in the original)

It is what has been also called ‘technical risk’, (Otway 1987). It is based on the ‘loss rate concept’, (Browning 1980). Given a certain magnitude of value loss for a failure the risk associated with failure in *n* occurrences as a function of *n* is an inverse law: risk ∝ 1/*n*

There are several assumptions that this view is based upon.

1. Events are independent and the truth of statements as to their expected occurrence is able to be defined probabilistically.
2. Probabilistic truth values about statements concerning the future can be based on statistical analysis of events from the past.
3. The truth values associated with risk are legitimated naturalistically.

4. Values of risk can be compared on a continuous scale with the value given by the parameter of the magnitude.
5. Magnitude values are objective or inter-subjective consensus as to what they are exists.

The naivety of this approach is due to an implicit assumption of naive empirical realism that the random events observed are due to real chance events of nature (Bhaskar 1978). A more sophisticated systems view has also been held that adopts a transcendental realist position, however, and defines the random events as being due to observations based on chaotic events produced by mechanisms with the number of parameters describing the underlying real mechanisms approaching infinity (e.g. Rodriguez-Iturbe et al. (1989) in the analysis of rainfall data). A constructivist view, in comparison to both, attempts to recognize when the use of a random generator metaphor or causal metaphor respectively is most appropriate and not to make any metaphysical claim in the attempt to legitimize the choice.

The naturalistic legitimation is also a consequence of the naivety of the approach. Even though the loss rate concept and use of probabilistic truth values is legitimate for certain modelling, the context-specific nature of this, specifically the social goals the analysis of the process is associated with, are not recognised. Neither is any reflexivity about the social role of the risk analyst carried out.

The assumption that risk as a measure is a continuous variable with the value given in terms of the parameter of the magnitude reveals a fundamental limitation, and the context-specific nature, of this method and definition. For example, if magnitude is given by  $x$  dollars and the probabilistic truth value is given by 0.5, then the risk is  $x/2$  dollars. Such a continuous variable exists only if the situation being modelled involves a number of individual events that can fail that approaches infinity, or in practice is very large. This is because probabilistic truth values are ascribed to precise statements which in turn refer to events which exist in a Boolean space - they either exist or they do not. A mapping from  $\{0,1\} \rightarrow [0,1]$  is involved. So the only way to get a continuous variable is if the magnitude for each failure is small and the magnitude used in the risk analysis is due to the summing of many failures. This type of analysis is well suited for manufacturing situations where the loss rate concept was developed. For example, if 1 in 1000 items produced are faulty in a run of  $10^6$  items where each item is worth \$1 if not faulty and \$0 if faulty, then the risk of failure is given by:  $\$10^6 \times 10^{-3} = \$1000$ . This would be the expected sample mean of objective statistical data and can be expected to have a low variance. However when considering the construction of a single item such objective analysis has no meaning. A fraction of a failure or success just does not exist and so

such a value has no meaning. Risk associated with flooding is in between these two situations. The expected sample mean of damage from a series of flood events in a certain period can have a very large variance. Chapter 7 explores this issue further and uses the results from Chapter 5 to improve the modelling carried out.

Now even if it is possible to apply probabilistic truth values because the number of events is very large, the result cannot be objective unless the value for the magnitude is also 'objective' because an inter-subjective consensus is reached. This is also very problematic. Unless the magnitude is a measure of a physical quantity, for example total rainfall in a period, the values are subjective, for example total damage in a period, and so obtaining an 'objective' risk value is problematic. It is even problematic whether inter-personal comparison of values is possible at all. This is an issue of great debate in the literature on the philosophy of economics. It is reviewed and developed in Chapter 8. Suffice to say here that very special conditions are demanded for decision-making involving values, and for the loss-rate concept to be applied for subjective values is extremely problematic. If possible at all it would require full inter-personal comparison and consensus to be achieved.

### **6.2.2 Modern Subjective Risk.**

In face of the difficulties associated with objective risk, a subjective risk model has been developed. It is arguably the orthodox risk theory, if the objective risk method can be called classical risk analysis. Its development can be traced through the Journal of Risk Analysis. It was expressed in a complete form by Kaspersen et al. (1988). They termed it 'Social Amplification of Risk' (SAOR). The SAOR model developed as a response to reactions against the objective risk model. 'Social' (Douglas (1982, 1986) and 'democratic' (Otway 1987) risk theories were critical of the technocratic and context-blind objective risk model. The SAOR model was an attempt to keep the social assumption or ideology of the objective risk model while admitting that values used were subjective. In doing so it has avoided the difficulty and deep questions that social or democratic risk theories asked about the social construction of risk. Accordingly the SAOR model was initially vehemently criticised, e.g. Rappaport (1988), Rayner (1990), Rip (1988), Fiorino (1989), Hadden (1989), Haimes (1989), Hance et al. (1989), Hansson (1989) and Otway and Wynne (1989). Their specific criticisms are reviewed in later sections.

To critically review the SAOR model here, the five assumptions of the objective risk model (Section 6.2.1) are considered so as to outline the modern subjective risk

adaptations in the attempt to overcome the limitations of the naive objective risk model.

1. The first assumption remains unchanged. However it is qualified through the use of Kantian metaphysics. It is still assumed that the truth of statements about reality is theoretically able to be given probabilistically by technical analysis, but the theory postulates that this is a transcendental reality (noumena) only perceived as phenomena which involve some subjectivity, i.e. risk *perception* is defined instead of risk *per se*. A radio-receiver metaphor is used by Kaspersen et al. (1988). There is a huge amount of literature on this. An example from Aotearoa/New Zealand associated with flood risk perception is Blackford (1990c).
2. The issue of risk perception becomes significant when methods for deriving measures of probability cannot be based on objective statistical data. Measures of truth value have to then be given subjectively with all the difficulties raised in Chapter 5. It is important to point out however that even though explicit subjective analysis is made it is still considered to be in response to an objective reality. The model assumes that risk perception is response to real random events, and hence the uncertainty aspects of risk, are open to discovery - as for objective risk. The model considers however that our inability to obtain enough data that are accurate interferes with our ability to discover risk as it really is. This view enables logically the deduction to be made that some perceptions are better than others because they are closer to the truth. Subjective perceptions are generally considered to magnify risk because of the predominance of risk-averse behaviour, and hence the name for the model.
3. Risk is still seen naively in this sense as having a naturalistic basis. The metaphysical underpinning thus allows the possibility of risk communication by people with more accurate (true) perceptions of risk to educate those with less accurate perceptions so that they have more correct perceptions. As with naive objective risk analysis, reflexive consideration of social roles and the link of these to the legitimization process of truth is not carried out. Rather the model justifies technical elite authority because they have supposedly access to a less distorted view of the truth of the probabilities involved.

The concept of bounded rationality emerges from postulated imperfection due to misperception. When people make decisions based on risk some are supposedly more rational than others. The availability of technical information determines the extent of the boundedness. In general the theory predicts that as people gain more information (are educated through risk education) they increase in rationality.

4. The need to produce a continuous scale for risk is extremely problematic when there is

not much technical information and/or there are not large numbers of events to be considered. It is side stepped through the definition of rationality from game theory. This is developed more fully in Chapter 9. Suffice to say here that game theory defines rational decisions and actions based on maximizing expected utility using the technical risk definition with subjective measures for both uncertainty and magnitude of consequences. Rationality is defined as the applying of the technical risk definition and minimization of the risk. Thus it suffers the critique of subjective probability already offered in Chapter 5.

This 'turn to the subject' is a feature of the modern paradigm in economic and decision theory as well. It is methodological individualism. It legitimizes the meaning of values which in 'objective' reality they are associated with could never occur. Therefore it is an attempt to legitimize reflexive incoherence. They are not meant to refer to an objective reality; they are just signs to be compared so that a 'rational' decision can be made by choosing the smallest one. The social construction of objectivity and hence need for reflexive coherence is not recognized.

Thus modern subjective risk analysis is explicitly an integral part of a normative technique. But because reflexive consideration of this is not carried out - methodological individualism is not questioned. The consequence is that with it being linked with the notion of bounded rationality and risk education, purely subjective decisions by a supposedly better-informed technical elite, has greater authority than the subjective views of others. The technique explicitly ignores the objective uncertainty and imprecision in the truth values and so decisions dictated by the technical elite are implemented as precise values. It is a technique akin to Popper's rational beliefs that fail to recognize where legitimacy comes from (see Chapter 4). What is missing is the carrying out of a double hermeneutic by risk analysts so as to determine appropriate contexts in which it can be used and where different analysis is required and/or needs to be developed. Rather there is general acceptance of incoherence and social integration into ideology and structural power relations of the institutions carrying out the analyses.

5. Risk perception is usually associated with the perception of the publics which are considered to be in various degrees irrational. In framing the situation like this the issue of non-objective magnitude values is also side-stepped. Just as the technical elite is legitimated to educate the publics about the correct (sic) subjective probabilities they can also define authoritative subjective magnitude values. Not to dictate like this is as extremely problematic as it is for objective risk. However there are several variations on how to attempt to incorporate public perceptions into a social choice, so as to legitimate methodological individualism in face of criticism that it is blatant dictatorship by a

technical elite. The theories come under the name behavioural decision theory and are addressed in Chapter 9. It suffices to say here that they do not and cannot address nor solve the problem of seeking consensus or even inter-personal comparison of magnitude values any more than they can address the issue of what are appropriate probability measures.

This issue has been well recognised in the risk literature for a long time but has been ignored in the SAOR model. McLean (1982) explicitly faced it in terms of the types of consent or legitimization of risk decisions. He outlines four types:

(a) Explicit consent that is democratic and requires some way to authentically come to a social decision. The research here concludes that dialogue and development of trust incorporating technical risk analyses of high pedigree is the only viable method. It does not rely on a naturalistic definition of human rationality at all.

(b) Implicit consent uses 'revealed' preferences based on market interactions by individuals as carried out in Risk Cost Benefit Analysis (e.g. Pearce 1981). Safety standards are then set through centralised decisions that mimic the trade-offs market data have 'revealed'. The difficulty with this method is that a market is not always or often the institution in which hazards can be adequately coped with. If markets work with hazards they tend not to be very traumatic. The result is that peoples' market preferences are deemed irrational, e.g. in insurance cover for flooding (Lave and Lave 1991).

(c) Hypothetical risk involves interviewing people to ask them what they would consent to under certain conditions. It is the method used in 'willingness to pay' analyses and subjective probability (e.g. Young 1990).

(d) Non-consent, which is authoritative and based upon externally determined values obtained by technical experts and systemically and dictatorially applied - technocracy. MacLean does not condemn types b-d but he does argue that a normative approach should seek to move toward greater consent rather than less. The SAOR model uses types c and d.

In conclusion, the modern subjective risk paradigm is problematic and incoherent and fails to resolve the limitations of the objective risk method. However it has managed to patch up the battered technical risk ideology, for the meantime at least, in authoritative (sic) literature.

### **6.2.3 Postmodern Subjective Risk.**

In response to the limitations of objective risk and that which the modern subjective risk analysis has reacted against is a new paradigm. It is usually associated with the term



‘social risk’ (e.g. Douglas 1982, 1986) or ‘democratic risk’ (e.g Otway 1987), but has also been explicitly termed ‘postmodern risk’ as well (Rappaport 1988).

The starting point of this approach is to consider the context from which risk emerges as a social construction. Allied to this is a non-naturalistic legitimization of risk. Instead of the truth of risk statements being due to a correspondence to an objective reality (or merely an ideological allusion to it in the case of modern subjective risk), truth is explicitly seen as being legitimated in reference to the achievement of social goals. Further, to define what the social goals are that provide the reference, requires reflexive consideration of the effect of the role of a risk analysis in the attempt to be ethical and hence democratic. This change in legitimization process allows solution of the problem associated with the other two approaches.

To introduce the change in perspective, application of the typology of freedom is helpful (see Chapter 3).

#### **6.2.3.1 Risk and the typology of freedom.**

That risk is a social construction that requires to be carried out democratically and with wisdom means that the expression of moral freedom should be sought. From this, full reflexivity enabling the explicit formulation of how to implement fundamental values, appropriate methods and institutions to operationalize it can be sought.

In contrast to this social construction of risk approach which is reflexively coherent and enables the incorporation of the principles and methods developed in Chapters 3,4 and 5, the naive use of technical risk and the use of the SOAR model engages in negative freedom and authoritarian positive freedom.

Risk in face of an objective world (including when considered to be imperfectly perceived) that is approached technocratically through elite authority to dominate, involves negative freedom in the attempt to try to escape from Nature that is not allowing itself to be controlled. That different social activity in the attempt to integrate with Nature can side-step the issue is not recognized, arguably because it is not the language game of elite control. When elite authority is used to define rational risk decisions, authoritarian positive freedom that denies the natural freedom of all subjects is implemented.

#### **6.2.3.2 Social Risk.**

The approach of social risk is to reflexively deconstruct the language games creating hazard and risk-producing situations. The aim is to create the ideal communication situation enabling dialogue and formulation of social goals democratically

and coherently. The forming of goals introduces participation with Nature that has possible harmful consequences. Hence the issue of hazards and risks is an integral part of the formulation of goals.

Initial research that coined the term *social risk* pointed out the culturally relative nature of rationality associated with risk, and instead of analysing it in terms of methodological individualism, they considered the culture as the entity. The culture is defined as having social goals that create certain interactions with its environment, and hence hazards and risk. Different cultures, by definition of what is a different culture, have different interactions and so create different hazards and construct different risks. Thus rationality is seen to be socially constructed and seen in functional terms, not able to be understood in terms of individuals and 'human nature' - as universal rules or bounds to information they may have. The focus is shifted from the individual to the culture. Rationality is seen to be distinct from understanding. Rationality is deduced from observed activities. Understanding is the term used for describing individual awareness giving rise to their responsible involvement in the social constructing activity that is culture.

#### **6.2.3.2.1 'Normal hazards'.**

An interesting analysis that can be interpreted as a transition from modern to postmodern subjective risk analysis arose in the work of Perrow (1984), resulting from his involvement in the United States inquiry into the 3-mile Island nuclear power accident. Perrow essentially contextualized risk analysis through a reflexive process to suggest that hazards are caused by the way risk is analyzed. In other words he deconstructed the types of projects produced unreflexively through the use of modern subjective risk analysis. The interesting aspect to his work is that he analyses from the point of view of the definition of rationality in risk methodology, suggesting that it is this that causes the hazards and the projects. The social risk perspective would turn it around the other way and say that the cultural activity of making projects according to competitive games creates the types of rationality outlined in normative terms in modern subjective risk analysis so as to legitimize the process. Whatever came first, it is true that non-reflexive application of modern subjective risk does at least legitimize, if not cause, existing development, as McLaughlin (1993) points out. However if risk methodology is critiqued then it can also serve as a tool for risk analysts operating as agents to change the culture and hence interactions with the environment, i.e. what are accepted as 'normal hazards'. But Perrow does not go this far. The research here extends Perrow's work.

Because Perrow does not consider the social construction of the methodology, he

focuses on the issue of rationality defined by methodological individualism. Perrow picks up on the use of heuristics in the situation of bounded rationality. He suggests that people using intuitive rules that are irrational or sub-rational in terms of the game theory definition of rationality, may have some information that the technical experts supposedly able to educate may not have. Perrow relativizes risk perception and in doing so does not base his view on a SAOR type model. Further he suggests that people's perceptions may be wiser than others may appreciate. In suggesting this he is opting for a requirement of moral freedom that the intrinsic value and voice of others be respected and heard. However he does not link it into a critical social framework, moral freedom and 'democratic' risk. Rather he suggests a static holistic view of functional rationality that the different persons and groups (ir)rationality somehow complement each other. He does not base this on a theory of social construction of bounded rationality normally associated with functional rationality. Neither does he interpret it as a negative situation as is normally done (see Chapter 9). So Perrow also ends up in an incoherent position by extrapolating his argument beyond what is legitimate, (Elms 1993).

Others have voiced similar views to Perrow's however, e.g. Haimes (1989) arguing for a holistic approach to risk and Rip (1988) arguing that 'social amplification' of risk should not be counteracted.

Perrow's relativity and respect for all risk perceptions and implicit acceptance of tacit knowledge or intuition can be incorporated into a coherent view by synthesizing it into the perspective of social risk.

#### **6.2.3.3 A coherent Postmodern Subjective Risk Method.**

Perrow's deconstruction and respect of all actors' voices and perceptions can be coupled well with the social risk perspective of hazards/risks being constructed by the interaction of a culture with its environment. This allows the incoherent relativism and holism of Perrow to be replaced by a constructivist basis for risk methodology as a function of context. Risk that is considered reflexively so that the context (the interaction with the environment) can be critiqued and changed also allows the methodology to be critiqued and changed. The key pin holding this reconstruction together is the notion of moral freedom that sees the possibility, through the development of caring and the building of community relationships, of trust through dialogue. This allows reflexivity to be institutionalized and so the interaction with the environment causing hazards and the need for risk analysis can be explicitly defined in terms of democratically chosen social goals.

However this institution is itself an ideal and to be achieved requires the

transformation of structural power, the unmasking of coercive ideology and the overthrow of dictatorship in all its forms by community empowerment. As mentioned in Chapter 4 the process of increasing participatory democracy is also the process of producing the ideal allowing democracy to work. Thus for a coherent postmodern approach to risk to be practical it must be able to forward this process as well as reconstruct social goals with hazards and risks faced realistically.

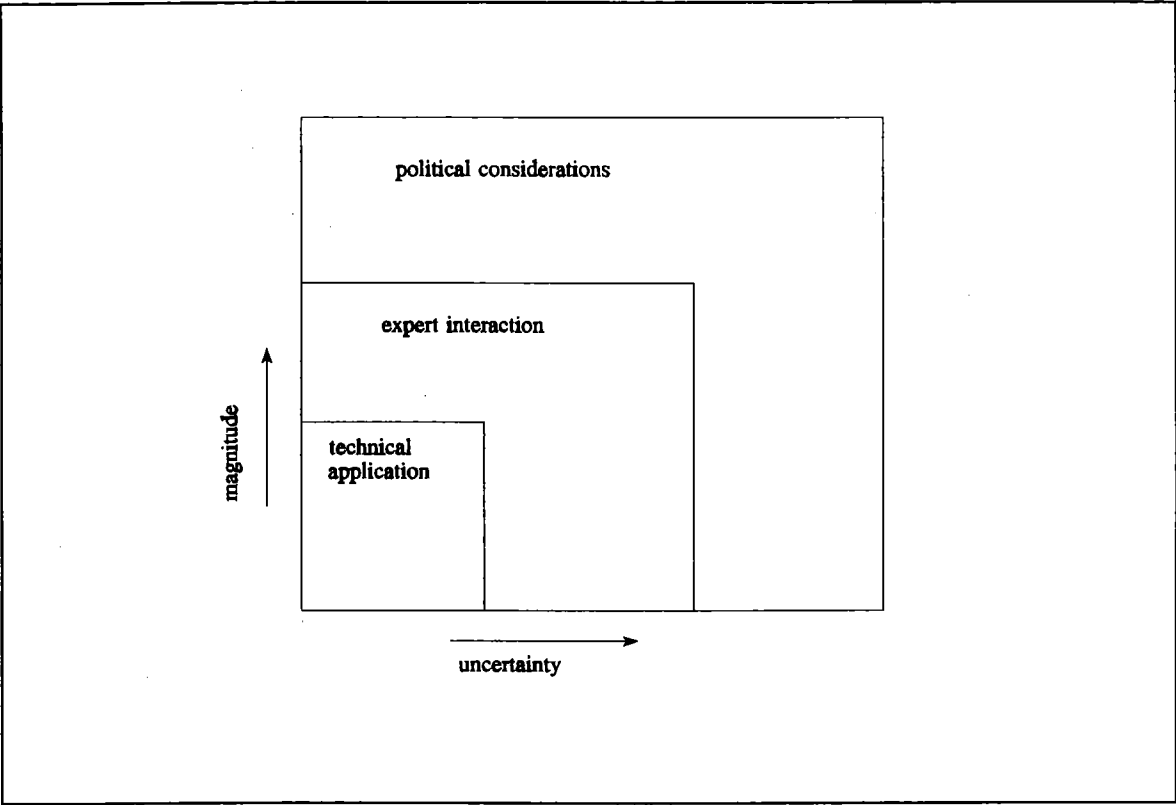
There are two requirements: to be able to incorporate uncertainty into the planning of social goals - which can be called proactive risk analysis - and a framework in which to consider the different types of contexts and methodologies that may be required. Having given away the assumption of rationality according to methodological individualism, there is no need to assume that there is only one way to analyze or represent uncertainty, nor only one methodology. The best basis to start with is the systems framework developed in Chapter 4.

The reflexive spheres imagery of Figures 4.5 and 4.6 can provide an initial basis for reconstruction. The outer sphere 1 of technical analysis can include technical risk analysis to the extent statistical data are available and stationarity with ergodicity can be assumed. This enables objective probabilistic truth values to be given. If trends rather than random events are considered then possibility and necessity truth values within approximate reasoning and fuzzy logic can be given. To the extent statistical data are available then they should be used as developed in Chapter 5.

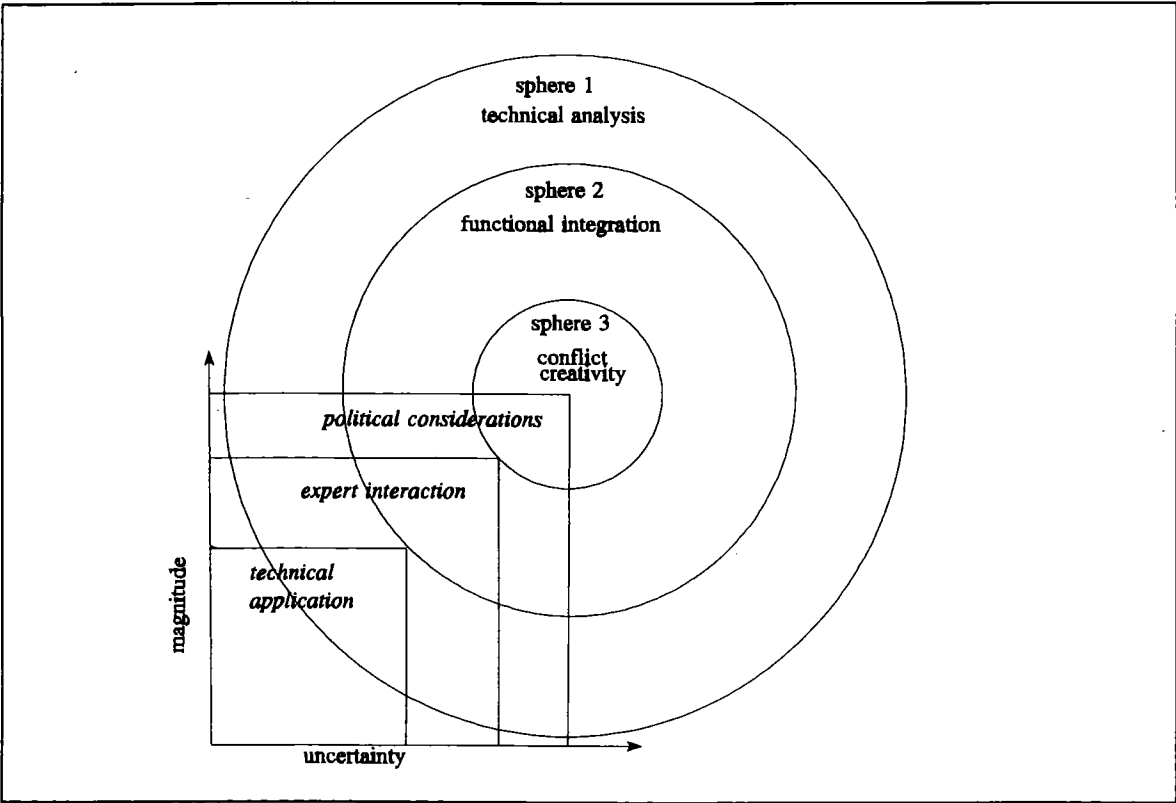
The middle sphere 2 of language games however requires reflexivity and represents where reconstruction occurs and cannot be considered separate from the innermost sphere 3. However, that the interaction with the environment is socially constructed means that risk associated with the outermost sphere 1 is created by what occurs in sphere 3 as well. The reflexive paradox is complete when realizing that the way sphere 2 conceives of sphere 1 affects what the risk is that is constructed. It is an aspect of the co-evolving process of adaptation.

Ravetz (1990) who has been commented upon by Rayner (1990) developed a typology of risk which enables the required types of risk methodology to be appreciated in terms of the reflexive spheres (see Figure 6.2, after Ravetz 1990; Figure 1).

The typology uses the classical risk parameters of uncertainty and magnitude, and defines the 3 types of context in terms of the two parameters. As such, the problems with the calculus of risk with these two parameters is not addressed, but it does provide a framework with which to start to consider the contexts that may require different types of risk analysis. The three spaces Ravetz outlines can be incorporated into the reflexive



**Figure 6.2;**    Social construction of risk.



**Figure 6.3;**    Risk and the reflexive spheres.

spheres imagery by redrawing them (see Figure 6.3).

The sacred or grace and creativity is the central component and is where conflict and confusion also occur. The two outer spheres are both concerned with the social aspect. But recalling again the point made above, because of the inherent relationship between social goals, hazard and risk construction, the physical and biological that make up the environment are included implicitly in the outer sphere of technical analysis.

Hazard/Risk here is not society-centred even though socially constructed. It can and needs to be concerned for possible hazards produced for other species in the ecosystem as well. Reflexivity and social justice are both necessary ideals if appropriate integration for adaptability is to be achieved and personal growth and meaning are to be achieved.

The features of cooperative games of trust and reciprocity are central for effective risk management where uncertainty reaches the level requiring social-functional integration for all social activities (O'Riordan 1982, Hance et al. 1989, and Otway and Wynne 1989). The various expert roles involved are required to form a holistic multi-disciplinary group (Spangler 1982, Rayner 1990, Hadden 1989, Hansson 1989, and Lave and Lave 1991).

The outer sphere is concerned with the actual community relationships between people and other creatures who make up and implement the cooperative functional roles of experts to implement social goals. The specific interest of this research is how the technical goals (physical, biological and ecological integrity) are achieved by the community. However other community activities, e.g. ceremonies, art and music in enhancing the environment, as well as all members of the community, are also crucial for community to exist.

As with the interaction of the spheres in the reflexive spheres imagery, the outer sphere and the inner sphere are linked. Conflict and creativity and dialogue are played out at the community level, and it is there that the process of social goal formulation has to occur by technical analysis to achieve goals directed for adaptive integration (Hansson 1989).

The reflexive process of the three spheres in the ground of wisdom to creatively overcome conflict can be nurtured constructively through a SSM process. The creation of root definitions accords with different community formulations of the issues needing to be addressed, and conceptual models are attempts to 'seed' coherent goals so as to encourage consensus-seeking discussion (see Chapter 9).

A final point that is crucial is that for this process to be successful, i.e. to maintain trust, the interactions with the environment modelled have to use realistic uncertainty and magnitude values; i.e the risk assessment must use appropriate mathematics (see Chapter 5).

## 6.3 A RECONSTRUCTION OF RISK METHODOLOGY

A reconstruction of risk methodology can be carried out in terms of the three spheres outlined above.

### 6.3.1 Sphere 1 risk.

The appropriate type of truth value depends upon the type of model being employed; whether causal, random generator or organismic metaphors are being used. But if non-probabilistic truth values are used then the loss rate concept for risk cannot be applied. That this is not widely appreciated is shown in an incoherent view expressed by the New Zealand Ministry for the Environment. In the sentence before defining risk as the product of probability and impact, it is stated that 'risk is the possibility of incurring damage or loss'. For example, if an approximate reasoning schema is being used for decision-making to consider the 'possibility of incurring damage or loss' and a future event is given a possible range then the calculus of 'risk' has to be reinterpreted. It cannot be 'the product of *probability* and *impact*.'

The use of the loss rate concept giving risk value as the expected magnitude of loss in a defined period is only applicable for a situation involving a large number of independent events, and where objective magnitude values can be given. Where this is not the case another approach is required. It is still required to consider the magnitude that can occur, but it is either a single occurrence or not an occurrence. A single event will have value given by its magnitude which has a truth value associated. In such situations the truth value of the event not occurring (or occurring - depending on what is 'hazardous') is the value that signifies 'risk', i.e. the probability, possibility or necessity that the event of magnitude  $x$  does (not) occur. This risk is a measure of whether or not a goal is achieved. Comparison of possibility functions as carried out by Equations 5.14-17 to give a measure of success are also signifiers of risk.

There are two fundamentally different ways that such success or risk values can be interpreted. They are the technocratic/bureaucratic and the precautionary/ecological approaches. With the technocratic approach, decisions about success and risk are given by how lower or higher than the goal modelled results are, depending on whether the goal defines a minimum or a maximum respectively. Therefore the greater the vagueness of either the goal or modelled result the less the success of failure and hence the lower the risk. However the precautionary approach reverses this and it is given by whether the goal value is significantly higher or lower than the modelled value when the goal defines a

minimum and maximum respectively. Therefore in the precautionary approach the greater the vagueness the greater the success of failure and hence the greater the risk. At the extreme, with no information the technocratic approach produces no constraints at all, and the precautionary approach prohibits all activity. The use of monitoring mentioned in Chapters 4 and 5 can be interpreted as a synthesis of the two approaches. Because there is the possibility of the consequences being alright, as suggested by the technocratic approach, activities are carried out. However the precautionary approach's recognition that the consequences are unknown is also appreciated and so monitoring is implemented so as to increase information which is used according to the precautionary approach.

The most common case where such risk needs to be defined is in the consideration of thresholds that are reached. For example a floodbank is overtopped which causes a 'catastrophe'. The occurrence of floods is an open system with events defined probabilistically, but catastrophes are rare and so realistically are interpreted within a Boolean event space of events either occurring or not occurring in a period. So the risk of a catastrophe is given by the fuzzy probability truth value of a statement claiming a catastrophic flood will occur in a certain period. It is fuzzy because even though floods are common and can be modelled stochastically (see Chapter 7) an analysis involving modelling the hydrological system using a causal metaphor and standard calculus produces vague results because the parameters are fuzzy.

Generally as events become less common and they are of concern as possible hazards, or need to be assessed for risk, their magnitude tends to increase (e.g Smith 1992). This is because of the properties of an underlying mechanism if a closed system is considered, and because of the calculus of the loss rate concept if open systems are being framed. So if a continuous variable exists to describe a phenomenon in a system, then the variable can be partitioned to indicate where events can be considered through the use of the loss rate concept and where a Boolean view of risk is required. In practice this is defined by the social context. If communities can maintain integrity through the application of objective risk analysis using the loss rate concept for particular events then such analysis is appropriate. When the community has to abstract the individual events as another event (e.g. floods to be a catastrophe) requiring a different community response then a Boolean analysis is required. How economic analysis is required to do this is developed in Chapter 5.

#### **6.3.1.1 Partitioned Multiobjective Risk Method (PMRM).**

Theory exists to define the partitioning of a continuous random variable. This



enables the consideration of technical risk associated with a single variable for multiple goals. It is termed the partitioned multiobjective risk method (Leach and Haines (1987), Mitsiopoulos and Haines (1989) and Haines et al. (1990)).

Consider a random variable  $X$  which represents magnitude associated with a risk. There are  $q$  policy alternatives given by:  $u_j, j=1, \dots, q$ . For each policy alternative probability density and cumulative distributions relating probability and magnitude exist:

$$P(a < X < b) = \int_a^b p_X(x; u_j) dx, \quad j=1, \dots, q \quad (6.1)$$

$$P_X(x) = \int_{-\infty}^x p_X(y; u_j) dy, \quad j=1, \dots, q \quad (6.2)$$

A partition is made on the probability axis given by  $\gamma_i, i=1, \dots, r$ .  $r$  is commonly set to 4. If  $r$  is equal to 3 it means that there is a separation into low frequency high magnitude, medium frequency and high frequency low magnitude types of events. The partition points,  $\gamma_i$ , are given by:

$$P_X(\beta_i) = \gamma_i \quad (6.3)$$

$$\beta_i = P_X^{-1}(\gamma_i) \quad (6.4)$$

For  $r=4$ , conditional expectation is defined by:

$$\begin{aligned} f_{ij} &= E(X | P_X(x; u_j), x \in [\beta_i, \beta_{i+1}]) \quad (6.5) \\ &= \frac{\int_{\beta_{i,j}}^{\beta_{i+1,j}} x p_X(x; u_j) dx}{\int_{\beta_{i,j}}^{\beta_{i+1,j}} p_X(x; u_j) dx} \quad i=1, 2, 3; \quad j=1, \dots, q \end{aligned}$$

where

$$\begin{aligned} \theta_i &= \int_{\beta_i}^{\beta_{i+1}} p_X(x; u_j) dx, \quad i=1, 2, 3; \quad j=1, \dots, q \\ &= \gamma_{i+1} - \gamma_i \quad (6.6) \end{aligned}$$

and

$$\sum_{i=1}^3 \theta_i = 1 \quad (6.7)$$

$f_{ij}$  is solved for as a function  $u_j$ . Thus there are  $r-1$  objective risk functions as part of a multiobjective analysis. These refer to different goals associated with the partition space. Classical multiobjective analysis considers the tradeoffs between multiple objectives. The same is done here. Define  $f_{cj}=f_{ij}$  when  $r=2$ , i.e:

$$f_{cj}=E(x|P_X(x:u_j), x \in [0, 1]) \quad (6.8)$$

This enables a cost function  $f_c(f_{1j}, f_{2j}, f_{3j})$  to be given in terms of the multiobjectives.  $u_j$  is representative of a continuous significant parameter and:

$$\frac{1}{\lambda_c} = \frac{\theta_1}{\lambda_{c1}} + \frac{\theta_2}{\lambda_{c2}} + \frac{\theta_3}{\lambda_{c3}} \quad (6.9)$$

where

$$\lambda_{ci} = \frac{-\partial f_c}{\partial f_i}, \quad i=1, 2, 3 \quad (6.10)$$

and  $f_c, f_i$  are the functions relating  $f_{cj}$  and  $f_{ij}$  as functions of  $u_j$ .

This enables effects on the marginal cost to be considered in terms of different partitions. Further if  $u_j$  is defined in terms of changes due to other significant parameters then the effect on the marginal cost of different parameters affecting policy alternatives can be addressed.

But PMRM in this form of it given by the authors above is only appropriate where the loss rate concept can be implemented. So the method is only appropriate where an open system is framed and the random generator metaphor is appropriate, and thus where magnitude is the consequence of very many of the events being summed, i.e all goals are concerned with sphere 1.

Two developments of PMRM are required if it is to be of practical help for floodplain management however. Firstly it has to be able to handle fuzzy probability distributions, and secondly it has to be able to handle situations where technical risk is not appropriate.

#### 6.3.1.1.1 PMRM with fuzzy distributions.

Fuzzy distributions can be expected to be the consequence of analysis involving scarce data. The relevance of this to hydrological data is explored in Chapter 7.

Therefore Equations 6.1 and 6.2 can be expected to be fuzzy with  $P(a < X < b)$  and  $P_X(x)$  to be described by possibility functions. Integration can be carried out numerically which

can be made isotonic by substituting in the negative of the lower increment. Therefore the calculation of  $\Pi(P(a < X < b))$

and  $\Pi(P_X(x))$  is straightforward through the further substitution of:

$$A_{ij} = \int_{\beta_{ij}}^{\beta_{i+1,j}} x P_X(x: u_j) \, dx, \quad i=1, \dots, k; \quad j=1, \dots, q$$

$$B_{ij} = \int_{\beta_{ij}}^{\beta_{i+1,j}} P_X(x: u_j) \, dx, \quad i=1, \dots, k; \quad j=1, \dots, q$$

$$B_{ij}^* = \frac{1}{B_{ij}} \Rightarrow \mu_{f_{ij}}(x) = \mu_{A_{i,j}}(x) \cdot \mu_{B_{ij}^*}\left(\frac{1}{x}\right) \quad (6.11)$$

A consequence of this is that Equations 6.7-10 are also fuzzy and so the ability to consider tradeoffs is lessened. Comparisons between possibility sets is required (see Chapter 5).

Another possibility to consider is if the goals that are considered are subgoals of higher compound goals. Then optimization and tradeoff between their optimization may be helpful. It may simply be fuzzy technical risk values given by Equations 6.1 and 6.2 as a function of the set of the policy alternatives  $u_j$ , or it may be conditional expectation  $E(x)$ , where  $x \in [\beta_i, \beta_{i+1}]$ , given by the numerator of Equation 6.6.

### 6.3.1.1.2 PMRM without technical risk.

This is required for situations where sphere 2 and 3 are involved. The first thing to be recognized is that if this is the case then Equation 6.7 does not hold as an upper limit to positioning of partitioning has to be defined, say  $k$ , where  $k$  is given by:

$$P_X(\beta_{i=k}) = \gamma_{i=k} : x \leq \beta_{i=k} \text{ covers sphere 1} \quad (6.12)$$

thus Equation 6.7 becomes:

$$\sum_{i=1}^k \theta_i = \gamma_k \quad i=1, \dots, n \quad (6.13)$$

Technical risk is not appropriate for two situations: either summed magnitudes that have to be considered over a period and hence are uncertain (see Chapter 7), or the concern is not for the sum of magnitude of events but rather for the risk of a single event. Concern for summed magnitudes over a specific period is important for functional

interactions of sphere 2 as it indicates imprecision of expected magnitude given a certain uncertainty of successful operation. Functional systems in sphere 2 can be resilient to system failure (be designed for low failure) if the flexibility required for components (imprecision of magnitude) is known. This is explored further in Chapter 7 and applied in Chapter 8 in terms of the dialectic between certainty and precision that occurs in all design. Chapter 7 explores the various ways this can be expressed in relation to goals related to hydrological concerns that are analyzed in sphere 1 through hard systems analysis. They are:

- (a) Exceedance probability given the time period of concern. The result is a fuzzy uncertainty.
- (b) Fuzzy maximum damage given that a defined maximum probability of occurrence is exceeded.
- (c) Fuzzy maximum probability of exceedance given that there is a certain damage exceeded.

#### **6.3.1.2 Scientific modelling and uncertainty.**

Box (1980) has defined the process of scientific learning as an iterative one having two parts; criticism and estimation. Models are seen to have two complementary parts: a predictive part allowing criticism of the system model (or in other words, its success), and a posterior part allowing estimation of parameters belonging to the model. As mentioned in Chapter 5 Box argues that objective analysis gained from statistics enables the predictive part allowing criticism to be developed and that this is a type of possibility function.

However Box does not leave theory an approximately vague sketch consistent with available data which this research has argued is necessary. Rather he sees the need to define precise subjective parameters to a theory that has withstood objective critique. He argues for the use of Bayesian techniques allowing updating of information to do this. He assumes that the resulting idealisation is necessary or at least an improvement, but gives no reasons for why this is the case. However he does appear interested in synthesizing subjectivist and objectivist views of probability and has been commended for doing so (e.g. Barnard 1980). Why this is an intrinsic good is not explained! However arguments reviewed in Section 6.4 suggest that it may be so that the battered paradigm of methodological individualism legitimizing the market institution is patched up for another round. Another interpretation can also be made however that considers situations where such idealization is appropriate. Bayesian techniques enable new information to improve

parameter estimation which can be useful as part of a monitoring situation where initially there is no information. However as information comes into existence the precautionary principle requires that possibility functions derived from actual data replace the Bayesian estimates. The significant feature of this discussion is that it is the indiscriminate use of idealization that is at fault, as is the indiscriminate use of methodological individualism.

### 6.3.2 Sphere 2 risk.

Sphere 2 is essentially concerned with defining what are the appropriate cooperative games to socially construct using an organismic metaphor to define functional engineered systems. For example, analysis of what type of flood protection will allow what type of business to be sustained. This has to span common and rare events. As already mentioned, this is explored fully in Chapter 8.

The reason this planning is considered to be a sphere 2 issue is because one of the functional roles operationalized to enable sphere 2 situations to be handled is monitoring that indicates where structural change may be required if the integrity of the system is to be monitored. This includes the public participation process of evaluating social goals as well as environmental monitoring. Such a role can also be seen to be part of sphere 3 situations. Two types of communication occur (see Chapter 9). The important point is that planning has to be a proactive process so that when sphere 2 or sphere 3 situations occur, appropriate functional roles, as part of contingency planning, are defined and able to be operationalized. The difference is that sphere 2 cases integrate information from institutionalized feedback loops as explicitly socially constructed morphogenesis/adaptation, whereas sphere 3 cases involve conflict and creativity criticizing existing institutions.

As already alluded to above, as well as defining institutions that allow sphere 1 situations to arise, sphere 2 is linked to sphere 3. Institutions have to be able to produce social planning or integrated functional wholes that avert *hazard*, i.e. contingency planning has to be developed where potential issues are seen through the public voicing of disquiet - even conflict - about existing plans so as to avoid conflict leading to complete social breakdown. So meta-procedures allowing reflexive critical review of existing plans have to be instituted. SSM is such a process.

A very revealing discussion of Perrow's (1984) is his arguing against the idea that risk aversion and its opposite is a function of voluntary or involuntary risk. He argues instead that it is not so much that risk is institutionally imposed that creates risk aversion, but rather that people feel powerless to avoid it - responsibility is out of their hands. He uses the example of the private motor car where it is institutionally imposed as a necessity

for (post)modern life, but people are far from risk-averse. The same applies with development on floodplains (e.g. Lave and Lave 1991). People do inhabit risky floodplains. However the imposition of a 'hazard' that they have no say in the running of, does create risk-averse behaviour. For example hydro-electric schemes hazardous to wildlife, and possible downstream effects on floodplains. Even though Perrow argues the case from a perspective of individuals it is indicative of the importance of meta-procedures like the SSM process to ensure democratic social planning in face of issues relating to hazards and risk assessment.

The functional roles existing to carry out contingency planning and instituting of ordinary social activities requires reflexive trust gained through the democratic process where responsibility is accepted. The stakeholders and actors have to trust in trust and cooperation so that such planning can proceed. The SSM process has to build faith and respect of other expertise that has proven itself worthy. Pedigree (both success and pertinence) has to be considered. This includes the incorporation of monitoring and integration of other information that is second order feedback and can direct morphogenesis. At present this is sadly lacking (O'Riordan 1982, Hance et al. 1989, Hansson 1989, and Otway and Wynne 1989).

### **6.3.3 Sphere 3 risk.**

As mentioned above, sphere 3 is linked to sphere 1 because the creativity, the discovery of meaning and awareness of sacredness, and the development of trust is central to both community relationships and the overcoming of conflicts. Both are expressions outside language games and objectivity. Where sacredness is seen, the culture's interaction with the environment is clearly circumscribed and some hazards are simply not created, and risk analysis is not carried out. The trust involved is 'simple' in both cases as the relationships created within the community in 'ordinary' life and in openness to grace is existential rather than functional. However as multi-disciplinary planning, integrative functional roles to operationalize contingency plans, and institutionalize morphogenesis, become developed, reflexive trust emerges in sphere 2 (see Chapter 4).

It is clear from this vantage point why experts in a reconstructive postmodern account can be considered to be 'elders' (Hall 1991). Their role is functional in the process of planning and helping to instigate the creation of contingency plans. But they also require an openness to grace in a simple trust of the unknown that is akin to the relationships within the community which places them within the community in the same trust and relationships. This is also where the notion of elders being wise members of a

community rather than an aloof elite comes from. They become centres or poles (to use Maori imagery) around which understanding emerges, society evolves and adaptation emerges. Naive relativism is overcome and a better than naturalistic 'objective' basis for analysis is found.

The result is a coherent framework in which to understand hazards and risk. It is the holism that Perrow was assuming but without appreciation of the reflexive and dynamic character of it.

## **6.4 RISK ANALYSIS IN SSM**

There are three steps in the process of SSM associated with risk, and there can also be considered to be three separate SSM processes.

1. To determine social goals. This requires some deconstruction of structural power and so involves conflict that needs to be talked through, but is mainly reconstructive. As concluded in Chapters 3 and 4 it is suggested that meta-ideals of reflexivity and sustainability are appropriate to guide the reconstructive process. It can be called SSM<sub>1</sub> (see Chapter 9).
2. To structure social activity so that the social goals are achieved. Here risk analysis and hazard awareness need to be incorporated, including through the use of monitoring. It can be called SSM<sub>2</sub> (see Chapter 9). This will feed back into step 1 and can result in criticism of sets of goals which may be found to be implausible. It is part of the iterative process within the wider SSM. The interaction is that between possible integrative CMs, including risk analysis, with the real world understanding of the stakeholders and actors given as RDs.
3. To be receptive to criticism of the sets of goals from the publics. This also feeds back into step 1. Eventually some incremental improvement in the situation will be accepted until future conflict brings about a further need for reassessment. Step 3 can be called SSM<sub>3</sub> (see Chapter 9).

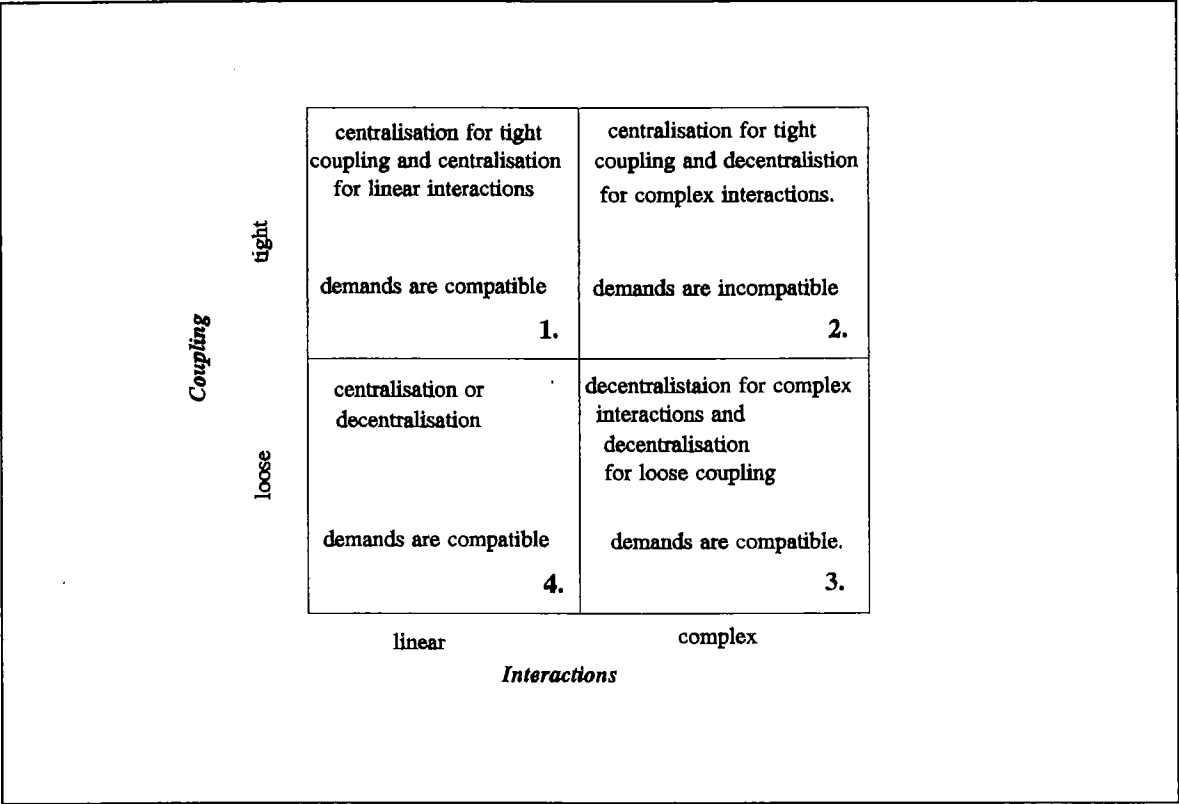
### **6.4.1 Typology of social structure and risk.**

Perrow defines two parameter pairs which produce a space of four possibilities. Complex-linear structure, and tight-loose coupling.

1. Linear interactions have planned sequences of events that are visible and immediately comprehensible. Complex interactions contain unplanned-for sequences involving feedback loops and incomplete information. It is recognised as the major cause of severe failures (e.g Perrow 1984) and Wulff (1991). However complexity is efficient if it does

not fail.

2. Tightly coupled systems occur in time-dependent processes, with single paths to achieve goals. There is little slack and substitution is difficult. Loosely coupled systems involve delays and standby mode with many ways to achieve goals. Tightly coupled systems have recovery planned out whereas in loosely coupled systems unplanned redundancies and substitutions are found and implemented.



**Figure 6.4;** Risk structure and administration.

Perrow goes on to outline the types of administration required for the types of interactions (see Figure 6.4, after Perrow 1984; Figure 9.2). Perrow’s conclusion is that only type 2 is problematic as it involves contradictory requirements and hence a no-win situation. So it can be concluded in considering floodplain management that type 2 structures are to be avoided.

In sphere 2 situations the system is time-dependent and so tightly coupled (e.g flood warning) and so centralized administration is required - i.e. reflexive trust to respect authority and expertise fulfilling functional roles. To avoid being type 2 means that the structure must also be linear. So visible and planned out procedures, or in other words explicit social construction, even if ‘inefficient’, are required. It is not possible to rely on



on-the-spot inspiration to find solutions creatively with impending catastrophic flooding. The risk is also too great to allow efficient tradeoffs to be made.

However in sphere 1 situations the process is not time-dependent. The planning carried out in sphere 2 to create the institutions for sphere 1 to operate within (management plans) creates loosely coupled systems with most features having multiple uses, and which are in standby mode most of the time. For example floodways can be used to graze sheep, corridors inside floodbanks can be parks, and wetlands can be flood attenuation reservoirs as well as mahinga kai and 'biodiversity centres'. Therefore the planning of the structure can be either linear or complex.

However there are two distinct processes involved in SSM which relate to whether the process is linear or complex. The planning of structure needs to be visible so that the rules of a management plan are known by the public, and options are clearly shown. However the community process of addressing conflict and discussing it is complex. Therefore both linear and complex systems need to be explicitly (reflexively) appreciated and respected. It is just as important to not attempt to rely on consensual decision-making in face of impending catastrophic flooding. Consensual decision-making should be used to determine linear processes to be implemented in preparation for such situations which require a linear administrative response.

#### **6.4.1.1 Risk trees.**

The process of determining the linear processes involved has to follow a sequence of events for both sphere 2 and sphere 1 situations. 'Risk tree' diagrams are required to be created as a function of time. They require to be seen as proactive tools to outline how to achieve goals. This way of perceiving and using risk trees is different to the classical way which was reactive and used to determine the probability of failure given a situation. Also unlike classical risk tree analysis which only used probabilities (usually subjective) between independent events, here any type of inference can be used. All the types reviewed in Chapter 5 are available. The most appropriate should be used. It is a question of modelling so that the calculus used is consistent with the type of system the situation is framed as.

For example a sphere 2 situation. Telemetry sensors may indicate the possibility of a flood and so a decision has to be made whether to initiate modelling of possible consequences given the information or not. Then as further information arises further decisions are made whether to initiate alerts and eventually evacuation or whatever other plans have been worked out will avert catastrophes occurring. Chapter 7 develops this

further.

#### **6.4.2 Different SSM processes.**

Structural change occurs in several time frames with different types of information input which correspond to the system structures associated with the three spheres and have been outlined above.

- (a) Short term activities that can exist as part of PMRM analysis. For example , the raising of stock to higher ground when a floodway is used. These exist in sphere 1.
- (b) Medium term planning of 'civil defence' operations to avert disaster that operationalize out-of-the-ordinary activities, e.g flood warning. Also planning of institutions to maintain sphere 1 (floodplain management plans). These exist in sphere 2.
- (c) Long term re-evaluating of plans because of conflict as to what are appropriate social goals - about what is held to be sacred. These exist in sphere 3.

Different styles of SSM are required to deal with the three types.

Type (a) requires close contact with the community to determine what are viable options and what sort of information is helpful. There is the need to understand the systems the community members and groups have in place - including relationships of loyalty and trust. A non-centralized approach is appropriate. Type 4 administration is required and  $SSM_1$  is employed.

Type (b) requires reflexive trust to be developed between groups (often volunteers) to follow instructions to plan (centralized administration) as an interdisciplinary team of 'experts'. This has to extend to the publics through 'civil defence' education and contact with the communities to determine what is realistic and what are priorities. Once again group loyalties, e.g evacuating whole close-knit communities together, and priorities that minimize trauma, e.g maintaining telephone contact as a high priority, are important. In the development of floodplain management plans this involves multi-disciplinary teams with reflexive trust between different groups of expertise. This has to be type 1 administration and  $SSM_2$  is employed.

Type (c) has to be a forum that regularly, and also when called into being necessary, can face conflicts in an open and non-authoritarian way. The attempt is to avert litigation occurring and the breakdown of community bonds of trust and authentic dialogue. It is appropriate that it should be non-centralised but centralized when it needs to be so as to make decisions and organise the type (b) process. Type 3 and 4 administration (Section 6.4.1) are appropriate. Initially the very complex situation of community airing of opinions and criticisms has to be faced. It is required that this be linearized so that social

goals can be obtained to direct restructuring in sphere 2. The linearization process is what SSM achieves (see Chapters 9 and 10).

## 6.5 RISK AND IDEOLOGY

Because there is the need to produce linear structures involving risk analysis when planning, it is necessary to have clearly defined ways to achieve the social goals being sought. Therefore the context throughout the risk analysis has to be in the forefront - risk analysis needs to be a proactive exercise for a specific task. Hence reactive risk analysis which does not define goals is inappropriate. However the use of complex structures may sometimes be appropriate if they can be expressed in non-reactive ways (see Chapter 8).

Keeney (1988) looks at the issue in terms of the fundamentals of risk analysis. He points out that the consideration of ethics is important for risk analysis because it is inherently prescriptive. For ethics to be included the inherent prescriptive nature of risk analysis needs to be made explicit. This means that the goals being sought need to be explicit, e.g proactive risk and carried out in a democratic way. If it is not made explicit then it is coercively ideological as certain value positions and resulting power relations are not reflexively critiqued, and hence the risk analysis legitimizes the ideology and social institutions in place. Reactive risk may be such an example because of its naturalistic legitimation referring to a human nature model of rationality, and claims of objectivity rather than a particular complex social situation for which it may be appropriate (Douglas and Wildavsky (1982); Otway and Thomas (1982); and Rotham and Lichter (1987)).

Commentators perceive two types of risk resulting from whether or not it is carried out coercively ideologically or not. Otway (1987) and Fiorino (1989) both discuss these and label them technocratic and democratic risk. Technocratic risk is that associated with technical elites using technical risk analysis imposed onto the rest of society. As a consequence of these two types of risk two types of risk communication have been commented on. If technocratic risk analysis is explicitly authoritarian then it is seen to be the 'old' risk communication of persuasion (Otway 1987 and Hadden 1989) or the attempt to produce inauthentic credibility like in advertising that is manipulative (Otway and Wynne 1989). Democratic risk on the other hand is seen to involve 'new' risk communication of dialogue and participation in decisions (Hadden 1989), or information empowering others to form their own opinions (Otway 1987), or information increasing community understanding, creativity and trust (Hance et al. 1989).

That technocratic risk does exist as coercive ideology is given empirical evidence by the loss of faith as to the honesty and competence of those establishing public safety

(O’Riordan 1982). This indicates that something is wrong with the classical risk approach. This realization forced the asking of deep and difficult questions about the social construction of risk. It implied that fundamental political/cultural change is required as well as change in the calculus of risk. This early awareness led to the development of the social risk critique trying to encourage democratic risk.

The deep and difficult questions asked by social risk commentators resulted in a backlash given by the SAOR model. What this model in effect did was prove that the classical risk approach was technocratic, as the SAOR model exploring supposedly scientifically why publics are irrational in magnifying risk, legitimized what had come to be called manipulative risk education. But because the questions being asked were very deep they have proven thus far to be too difficult and the SAOR model is holding sway, with risk communication now a dead issue in the literature. Risk analysis has become again the realm of technical analysis - the paradigm shift did not/could not occur because the social structure power relations legitimated by technical analysis has not changed. The reflexive awareness did not produce a change in practice and so a change in worldview did not occur (see Chapter 3 and 4).

However some research has remained on this issue. Not surprisingly it is based on the work of a mathematician critical of the calculus of mathematical uncertainty. Rayner (1990) taking up Ravetz (1990) has outlined types of ideology and structural power in terms of cultural types. He related these to the types of risk analysis carried out. He outlined three types:

1. Market
2. Hierarchical
3. Egalitarian collectivist.

He characterizes market and hierarchical culture as using technical risk as a coercive ideology. Market culture is seen as carrying it out as structural power and ideology through the use of implicit and hypothetical consent seeking. This is discussed more in Chapter 8. Hierarchical culture is seen as carrying it out with dictatorship using non-consent. Egalitarian collectivist culture is that which produces and is supported by democratic risk analysis.

The discussion thus far has indicated that for ethical and realistic reasons democratic risk is usually the most coherent type. This implies that egalitarian collectivist culture is usually the appropriate type of culture within which to interact with the environment. This raises a dilemma. To promote egalitarian collectivist culture is a political issue. The use of a coherent risk methodology will be only one step in the

process of producing it. It is easier for risk analysts to be incoherent and to socially integrate into hierarchical or market culture, for example, as done by the Aotearoa/New Zealand's Ministry for the Environment (1994).

However the call for egalitarian collectivist culture appears from all the disciplines reviewed so far, and is repeated in the chapter on economics as well. Therefore it is a conclusion here that a fundamental change to such a culture is required if coherent social activity (resource management, including floodplain management) with the environment is to be achieved - for reasons of risk and hazards as well as for other reasons. This is the political context in which risk analysis rests at present. However this does not imply the need for political activity to change society's institutions, but rather the nurturing of personal integrity, improvement of community development and ecosystem integrity. The change needs to occur as improvement of existing institutions through more appropriate and responsible use of technical analysis and management, including SSM. The change to be successful requires to be creative and to be based on the improvement of personal relationships rather than increased alienation through imposed structural change of society.

# Hydrology

Hydrology is the knowledge concerning natural processes involving water flow in the water cycle (see Figure 7.1). It is usually assumed to be given by technical scientific knowledge of objective natural reality. Scientific analyses of physical processes are carried out to gain this information. Both reductionist and system analyses are used.

For use in engineering praxis, hydrology forms part of the total knowledge needed. It is from this context that hydrologic analyses draw their meaning and value for engineering method. It is from this context that the hydrological knowledge is legitimated for engineering and able to be called true in the concern for floodplain management.

## 7.1 INTRODUCTION

Scientific analysis and the resulting information is woven together into a structure with specific goals which are technical subsystems. These technical subsystems exist as means for defined social goals with functional rules. For the system to be coherent requires that the functional roles are determined according to principles developed for community development. The social goals exist logically prior to the technical goals and hence the hydrological analyses. However the constraints determined through the hydrological analyses may influence what the community decides are its goals and issues. So the process is an iterative and dialogical one between the hydrologists and all the members involved in the study. To avoid being coercively ideological, hydrological information must not hide uncertainty and imprecision. It is used in a coercively ideological way if practitioners use scientific legitimation to mask hidden agendas or to unreflectively support unjust structural power. There is some evidence that this is done with hydrology (Beven 1993).

In endeavouring to develop a postmodern epistemology for hydrology, Beven (1993) points out how hydrologic analyses are often extreme idealizations, and as such are being used as prophecy not based on substantive evidence. He correctly condemns this as abuse of scientific legitimation (appropriately called scientism), but fails to make the point that what is wrong with it is not that prophecies are being made, but rather that the prophecies are masking through naturalistic legitimation claiming objective reference free of context. A prophecy can have a legitimate social function as long as it is recognised as

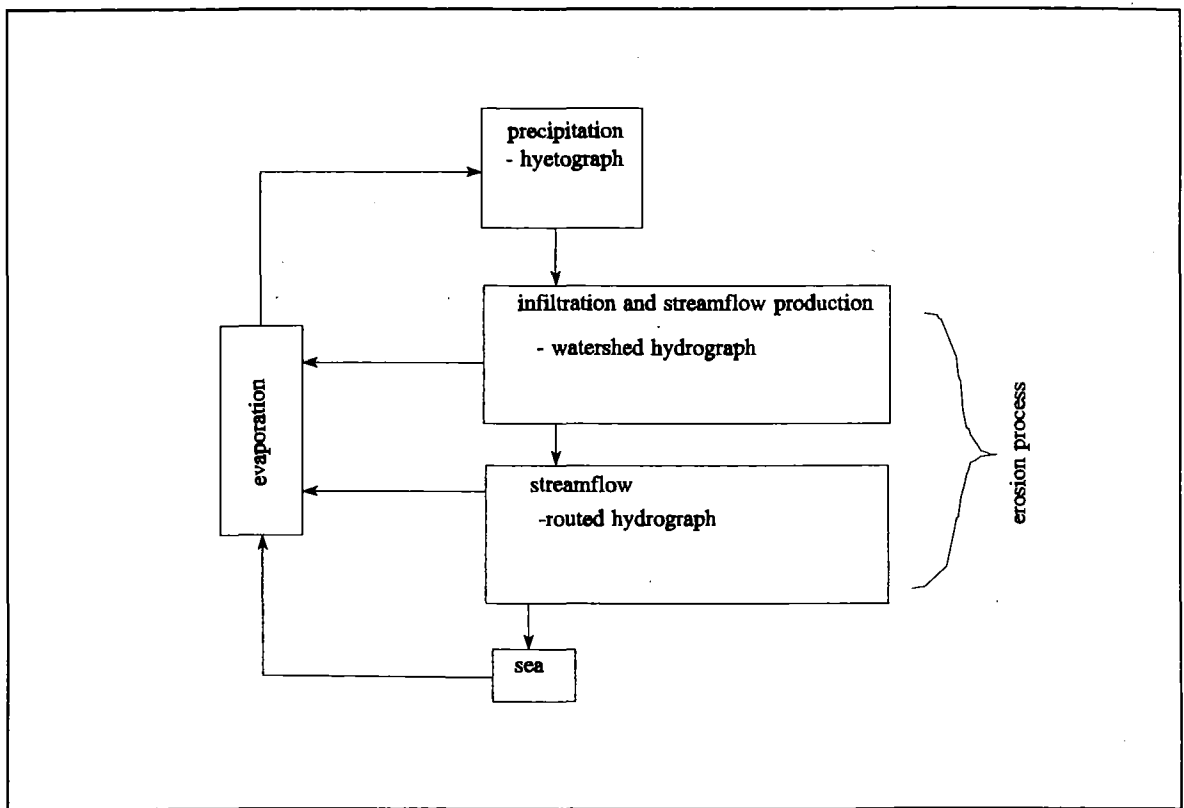
being legitimated accordingly. If it is linked to moral intuition, and the result of community dialogue, it may actually have an important social function with even a high pedigree. What is wrong is how particular social agendas are claiming scientific legitimation to mask or rationalize their activities which may not have a socially acceptable role. For example, the use of flood frequency data is mainly to justify a certain type of economic analysis which supports specific development agendas which are not made explicit. This is explored later on in this chapter and in Chapter 8. Beven (1993) correctly points out that it is prophecy, but it is more than that. It is also a social ordering activity and as such acts as a self-fulfilling prophecy which can be successful in achieving its agendas, for a while.

To make sure that hydrology is not being abused in this way it is necessary to deconstruct the hydrology and the methods used to analysis it. This involves looking at the uncertainties and imprecision, how the systems are legitimized and how they are used, i.e. what they may be rationalizations for, and especially the technical goals they may be used to help achieve. Then the technical requirements for reconstruction based on the ethical meta-values developed in previous chapters are outlined so that relevant hydrology that can be used coherently in floodplain management is presented.

### **7.1.1 The physical system.**

Water flow modelling is in response to the physical reality of the water cycle. The aspects which are focused on in modelling in floodplain management are the parts from precipitation through watershed runoff (including the effect of infiltration and ground flow) to flow down river channels into the sea (see Figure 7.1). The water movement is influenced by the physical geography of the area; geomorphology and vegetation, and hence also by the human activity which influences these factors - resource use practices. The hydrological modelling of the physical situation can be carried out by considering the physical characteristics themselves. The influence of human activity enters into the modelled system through how these characteristics are changed. Therefore for the modelling, the influence means that the parameters may have to be changed, and are also to an extent contingent. The future is uncertain because the factors affecting the human activity are factors extraneous to the system being investigated. Also reflexively, hydrological analysis may affect what these are, because hydrology is used within engineering praxis.

Widening the system to include the factors affecting human resource use is carried out in later chapters looking at the floodplain management system in terms of economics,



**Figure 7.1;** The hydrological cycle.

decision-making and aspects of policy analysis. The information gained from modelling the hydrological system is part of the information system used in floodplain management. It helps in technical design used to fulfil social goals determined by overall management to serve as a relevant reconstruction.

There are five aspects of hydrology which need to be woven into systematic (coherent) methodology for floodplain management.

1. Precipitation data.
2. Watershed modelling.
3. Stream routing.
4. Flood frequency analysis.
5. Bank erosion.

The modelling of precipitation is used as input to the water flow modelling of watershed and stream routing. The modelling of water flow is used as part of flood-warning systems, and in the simulation of possible flood scenarios. Flood frequency analysis is used in the analysis of risk analysis. The consideration of bank erosion is used for technical design to mitigate flood damage.

The research here does not focus on extending the development of these models,



although it does this as well. The focus has been rather on how the information produced from the modelling can be used coherently so that the full meaning of the information can be used and not abused. This means rigorous analysis of uncertainty and imprecision is carried out so that use of prophecy is legitimately carried out for explicit goals within floodplain management, rather than coercively.

## **7.2 PRECIPITATION**

Stochastic models are commonly used. These assume that the system is so open, with such a large number of determining parameters affecting the result, that the events when analyzed are observed as random. However chaotic deterministic models have also been suggested. Rodriguez-Iturbe et al. (1989) have shown that precipitation data within individual storms with data taken every  $\frac{1}{8}$  of a second are the result of four parameters producing chaotic results. Chaotic results mean that random processes can show trends. Two complementary effects occur. Rodriguez-Iturbe et al. describe them as the 'Noah' effect and the 'Joseph' effect. The 'Noah' effect means that sudden variations can occur. The 'Joseph' effect is that when they do occur they are maintained. The two together mean that 'Trends in Nature are real, but that they vanish as quickly as they appear.' Weekly data are however stochastic. Annual data show trends but there are not enough to be able to carry out an analysis for chaos so as to determine what the number of determining parameters are. Also it must be remembered that chaotic models still model randomness. The consequence of chaos is that qualified and bounded use of a random generator metaphor has to be applied.

But in floodplain management issues data are in the scale of weekly events and so deterministic modelling adds no information.

### **7.2.1 Stochastic models.**

There are two approaches used: non-spatial and spatial models. Non-spatial models consider the process from the position of what occurs at a fixed point, and use this to represent a region. Spatial models consider the evolution of precipitation events in time and 2-dimensional space.

There is much evidence that precipitation storm events in non-spatial models can be modelled as a stochastic and Poisson process (Ozturk (1981), Revfeim (1981) and Morrison (1988)). The requirements are that the storm events be independent of each other, and that the distribution of the depths of storm events be independent of the distribution of occurrence of storm events.

In a Poisson process there is a constant potential for events to occur even though the exact occurrence will not be known. Mathematically this means that the probability of an event, in a given short period  $\Delta t$ , can be given by  $\lambda$ . Hence the probability  $P$  of there not being an event in a period  $s$  where  $s=n \cdot \Delta t$  is given by:

$$P = 1 - (1 - \lambda)^n \quad (7.1)$$

Taken to the limit, where  $\Delta t \rightarrow 0$  and  $n \rightarrow \infty$ , the period  $s$  between storms is described by a -ve exponential distribution (Haan 1977):

$$P(s) = \lambda e^{-\lambda s} \quad (7.2)$$

$\lambda$  is estimated by the inverse of the expected value of  $s$  by both the method of moments and the maximum likelihood methods. From Equation 7.1 the probability of the number of events  $N$  in a period  $T=m \cdot \Delta t$  is given by the binomial distribution:

$$P(N) = \frac{m! \lambda^N (1 - \lambda)^{m-N}}{N! (m-N)!} \quad (7.3)$$

Taken to the limit where  $\Delta t \rightarrow 0$  and  $n \rightarrow \infty$ , the probability of  $N$  events in a period  $T$  is given by the Poisson distribution (Hines and Montgomery 1980):

$$P(N) = \frac{\lambda T^N e^{-\lambda T}}{N!} \quad (7.4)$$

This model can be expected to accord with the physical reality of a constant potential being supplied by the energy from the sun evaporating water thus producing the hydrological cycle. The exact occurrence of a precipitation event at a particular position is not known but for a period  $T$  a probability function can be synthesized from statistical data of the occurrence of precipitation events. The randomness occurs because of the spatial distribution of precipitation events. It can be argued that over the whole area of the Earth, precipitation and evaporation are constant and equal, but that over subsets of the surface, because of the variability of the movement of precipitation events the equality does not hold, especially over short periods. So at the limit, when considering a point, as in non-spatial analysis, a random distribution can be expected to occur even though evaporation may be relatively constant.

Some non-stationarity may be expected to occur in non-spatial models because the potential for evaporation does change due to seasonal and sunspot cycles. This can be expected theoretically to vary the expected probability function modelling the occurrences.

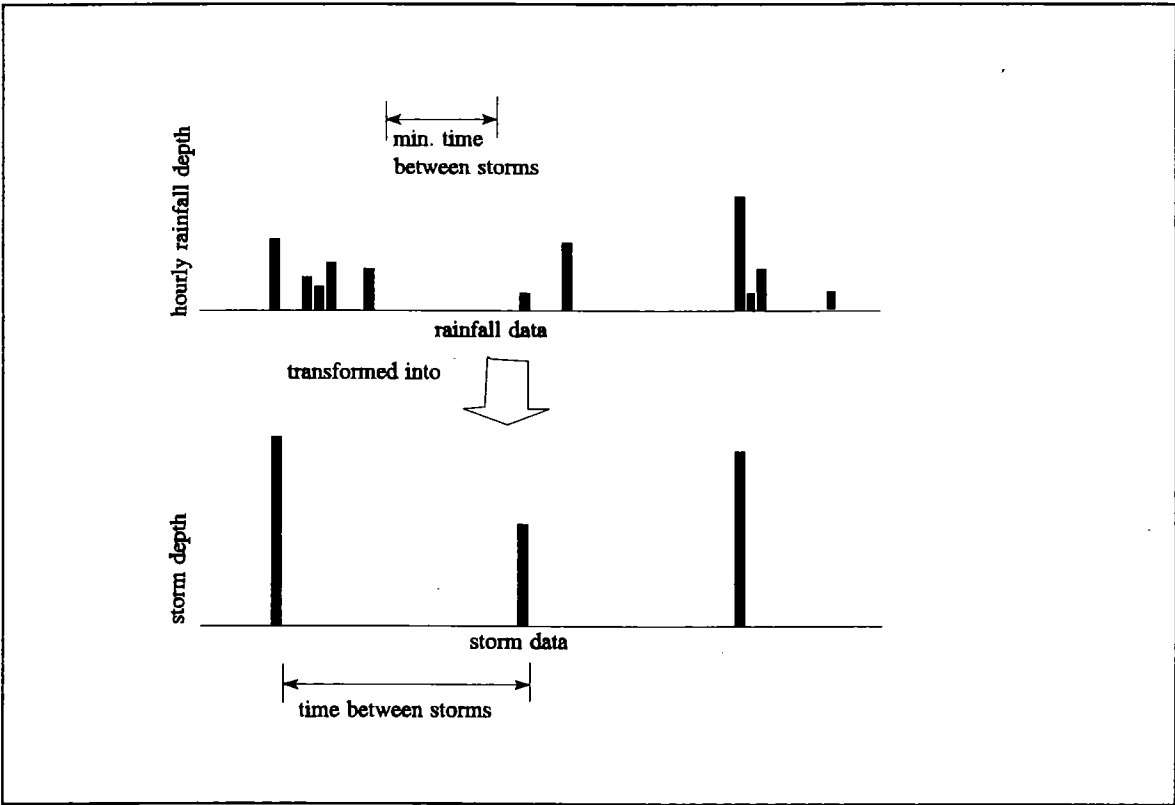
Spatial analyses relate precipitation between points in an area. Spatial models may be

useful for analysis of short periods in real-time modelling. Potential applications in floodplain management may be for some situations concerned with flood warning.

**7.2.1.1 Definition of model parameters for non-spatial modelling.**

A distinction has to be made between precipitation data, which are a function of the data recorders as well as the precipitation events, and precipitation storm events which are what are being sought to be modelled. ‘Storm’ events by definition are expected physically to be able to be modelled by a Poisson process. So precipitation data have to be synthesised into ‘storm’ events. This is only possible if the interval between precipitation recording is less than that of the expected duration of the ‘storm’ events. Hourly data readings were found to be adequate when modelling Christchurch data, but daily readings were not (Morrison 1988).

Synthesis can be achieved by aggregating precipitation data which follow other precipitation events within a certain period. This period defines what is the minimum period between storm events (see Figure 7.2). It must be recognised here that ‘storms’



**Figure 7.2;** Synthesis of storm events.

are purely an abstraction to give a label to what forms independent events, in the attempt to apply a stochastic model. It cannot be expected to refer to what is called a storm in

*natural* conversation.

The value of  $s$  in Equation 7.2 can be determined from the synthesised 'storm' data. From these synthesised data a regression can be used to estimate values for  $\lambda$ . However a complication occurs in that synthesis of 'storm' data is dependent on the minimum period between 'storm' events. Hence the regression cannot be expected to produce an exponential regression. However assuming that a stochastic model can be made then the 'wrong' minimum period between storms can be expected to be the sum of  $k$  -ve exponential distributions, i.e. a gamma distribution:

$$G(s) = \frac{\lambda (\lambda s)^{k-1} e^{-\lambda s}}{\Gamma(k)} \quad (7.5)$$

A -ve exponential distribution can be considered to be a special case of the Gamma distribution, where  $k=1$ . So regressions onto a Gamma distribution as a function of the minimum period between storms allows determination as to what is the 'correct' minimum period between storms and hence what is the definition of a 'storm' so that precipitation data are able to be modelled as a Poisson process. Estimation of parameter values for the Gamma distribution is easily given by the method of moments but not for the maximum likelihood method where approximations have been used (Haan 1977). The use of auto-correlation can aid in predicting the 'correct' minimum period. Morrison (1988) carried out this analysis for Christchurch rainfall hourly data and found that the 'correct' minimum period between storms was 6 hours. Precipitation events less than 6 hours apart were considered to be the same storm event. It was also found from an analysis of the distribution of the duration and intensity of storms that different precipitation generation mechanisms were present; i.e. between convective storms and frontal systems.

Once 'storms' have been thus defined, allowing a stochastic model to be applied, the statistics of the synthesised 'storm' events can be regressed to determine the parameters of the Poisson distribution through the use of the estimate of  $\lambda$ .

Statistically significant regressions onto the expected distributions resulting from a stationary stochastic process have been found (Ozturk 1981, Revfeim 1983, and Morrison 1988).

Expected non-stationarity is not found in the Poisson process producing the occurrence of storm events, but rather in the depth of precipitation resulting from the storm events (Revfeim 1983 and Morrison 1988).

Non-spatial analysis models random passes by 'storms' over it. The moving 'storm' as a product of the nearly constant potential of the sun's energy evaporating water, thus

accumulating potential precipitation, is described by a Poisson process. A ‘tipping bucket’ analogy has been used to describe the process (Haan 1977). This use of metaphor should be interpreted as the explicit recognition of the use of metaphor. It is used in the discussion below in conjunction with random generator and causal metaphors. The model assumes that the propensity to drop rain is not dependent on the amount of water vapour already accumulated. Consider a near-constant potential accumulating water vapour of  $q$  in a period  $r$ , and that the resulting ‘storm’ has a probability  $p$  of dropping it in a period  $r$ . Assuming that all the accumulated water vapour is dropped when it does rain, the probability of rainfall  $x$  in a period given by  $n \cdot \Delta t$ , where  $x=nq$ , is given by:

$$P(nq) = 1-(1-p)^n$$

which taken to the limit where  $q \rightarrow 0$  and  $r \rightarrow 0$  is:

$$P(x) = pe^{-px} \quad (7.6)$$

$p$  is estimated by the inverse of the expected depth of precipitation in storm events.

It is important to note that the period  $r$  is not in any way related to  $s$ . Two distinct processes are involved and hence independence between the two is assumed. The time between ‘storms’ passing over a point is not related to the storm’s accumulation of water vapour.

Therefore the depth of storm has been modelled as having an expected depth of storm precipitation given by a -ve exponential distribution. The parameter of this distribution is found statistically to significantly follow seasonal variation according to a single cycle harmonic in Christchurch data (Morrison 1988). A stationary random distribution null hypothesis had to be rejected for Christchurch data when seeking a confidence of at least 90%.

### 7.2.1.2 Expected Rainfall.

Analysis of expected rainfall over an extended period can be determined with the use of the two independent distributions of the occurrence of storm events and depth of precipitation in storm events. The ability to do this is an advantage in using a stochastic model over empirical statistical models for rainfall. The distribution function for the expected total depth of precipitation  $X$  in a period  $T$  is given by Ozturk (1981):

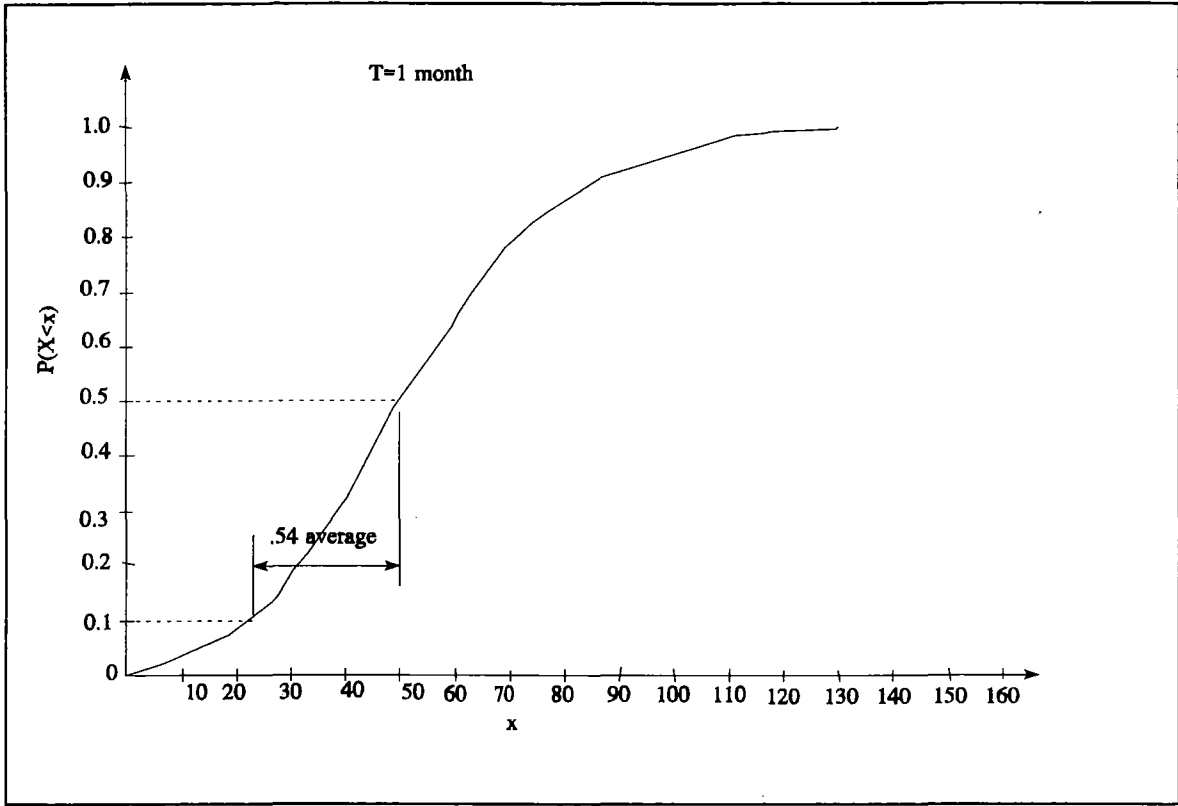
$$P(X \leq x) = P(N=0) + \sum_{k=1}^{\infty} P(X \leq x | N=k) \cdot P(N=k) \quad (7.7)$$

where  $P(N=k)$  is the Poisson distribution for occurrence of storm events, and  $P(X \leq x | N=k)$  is the probability of depth of precipitation given that there have been  $k$  'storm' events in the period  $T_s$ . N.B. This assumes independence between the two distributions.

Using the -ve exponential density function for precipitation depth per 'storm' event means that  $P(X \leq x | N=k)$  is the integral of a Gamma density function.

$$P(X \leq x) = e^{-\lambda T_s} + \sum_{k=1}^{\infty} \frac{(\lambda T_s)^k e^{-\lambda T_s}}{k!} \int_0^x \frac{\rho^k y^{k-1} e^{-\rho y}}{\Gamma(k)} dy \quad (7.8)$$

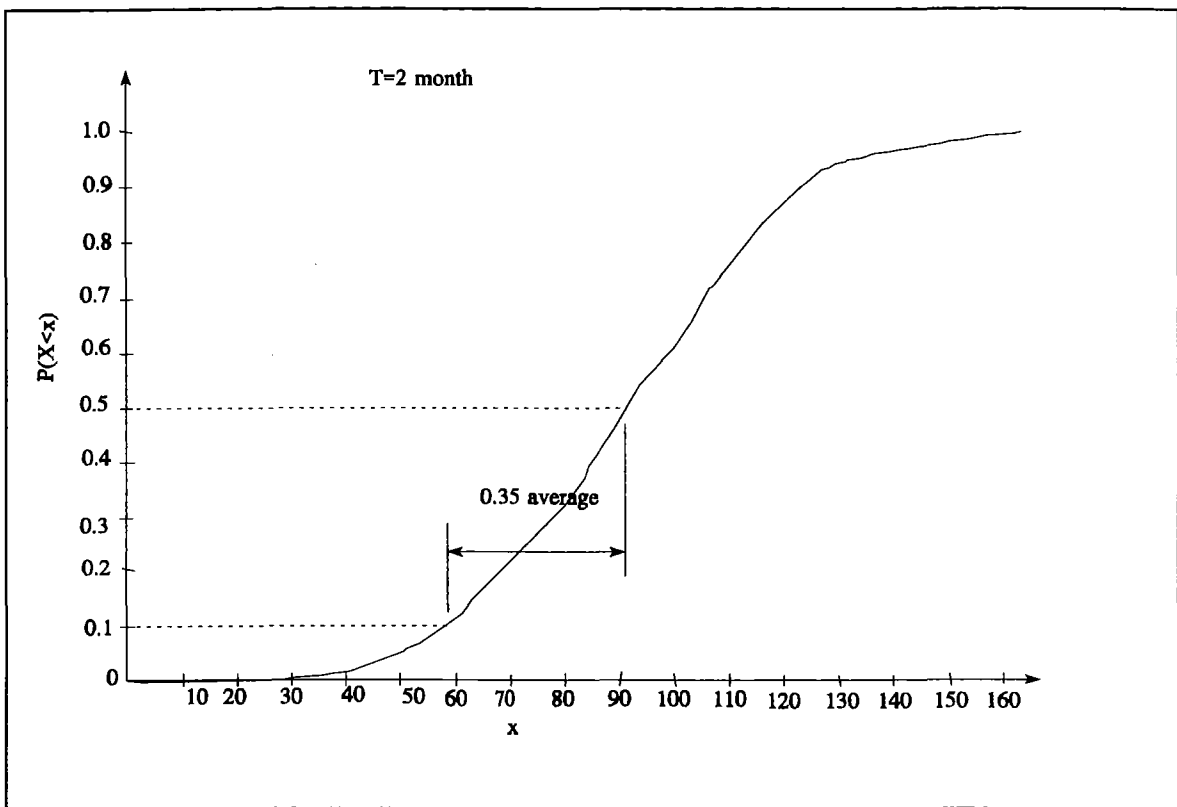
Ozturk (1981) has attempted to characterise the resulting distribution by parameters and been critically reviewed by Revfeim (1983) for the analysis of the results he produced. To avoid debate over superiority of different methods of achieving parametric solutions, Equation 7.8 can be solved numerically (see Appendix A.1). It is considerably simplified even further if the Central Limit Theorem is invoked for values of  $k > 12$  (see Section 7.6).



**Figure 7.3;** Expected rainfall depth in one month.

The resulting distribution indicates how as rate of events increases over the period  $T_s$  (i.e. the longer the period  $T_s$  for a given stochastic process being modelled) the more precise the resulting information is. Graphs of two different periods are included in Figures 7.3 and 7.4 to illustrate the point.

The analysis of expected rainfall depth is not directly used in floodplain



**Figure 7.4;** Expected rainfall depth in two months.

management. However a similar analysis of a stochastic process is carried out when considering expected damage from flooding over a period (see Section 7.4 and Chapter 8).

### 7.2.2 The use of precipitation data.

Precipitation hyetographs recorded by rain gauges are used to provide data to test simulation models for stream flow. Once adequate streamflow models have been developed, scenario precipitation events can be used to simulate possible streamflow that needs to be considered in floodplain management.

In associated water resources management, concerned with drought and irrigation rather than floods, the model developed above for expected precipitation can be used directly in water scheduling (Morrison 1988).

## 7.3 WATERSHED MODELLING

Watershed modelling forms the interface between precipitation models and river routing. Watershed dynamics are complex and can only partially be modelled by linear models. Storage through ground water flow produces a base flow, and so modelling the production of flood events from precipitation storms is not simple. Further the antecedent

conditions of the degree of water stored has an influence on the overland flow producing flood events. Uncertainty as to antecedent conditions can be considered to add openness and hence randomness to the overall water flow system model. However empirical and kinematic wave modelling of overland flow are commonly used, with parameters defining percentage of ground saturation. The weakness in these models is that as well as the storage of water decreasing the intensity and absolute value of a flood event, the integrating effects of the rates of groundwater storage can lead to the overlapping of outflow from precipitation storm events which adds some possible dependencies into the stochastic modelling of flood events. Never-the-less it can be defined that base flow is that which is formed by complex integration effects in groundwater and so definition of 'floods' implies independent events.

In scenario modelling the complexity involved in relating levels of watershed to previous events (even independent flood events have magnitude affected by antecedent conditions) means that imprecision is a required feature of analysis. In real-time modelling antecedent conditions are a significant parameter. HEC software provides a flexible modelling tool to carry out watershed modelling (e.g. Ford 1991), but would have to be adapted for real-time modelling and for the use of possibility functions to define imprecision for scenario modelling.

## **7.4 STREAM MODELLING**

The modelling of streamflow usually involves a deterministic analysis given by the set of St Venant equations for hydraulic flow. These are the application of Newton's laws of mechanics to fluid flow, i.e. they can be considered to be a close description of the real physical mechanism present although the parameterization of them always involves simplification. Parametric error is always present.

Standard commercially available software solves the system of St Venant equations to various degrees of simplification. The sophistication of the software is dependent on the extent simplifying assumptions are made. A simplifying assumption made in most commercially available software is the simplification to one-dimensional flow. Here it is assumed that the water flows only in a straight line. However complicated networks to attempt to model 2-dimensional surfaces can be carried out. For example, one of the most popular commercially available software packages, MIKE 11.

If a one-dimensional flow model is used and there is the added simplification that momentum effects are considered negligible then the St Venant equations simplify further to the kinematic equations. This method, along with empirical models, is included in



A two-dimensional flow model is more realistic, but far more difficult to model. It has the advantage that the riverflow can be modelled to overtop river banks, and so depth of flooding from the overtopping can be determined in the outlying areas. Software is commercially available to do this. Fedra (1991) gives a review of software available at the time of his writing.

For all of these models the equations are solved numerically. For the kinematic model finite difference modelling is used and for the St Venant equations for 1 or 2 dimensional flow, either finite element or finite difference methods can be and are used. For the kinematic equation method a 'rating curve' relating stage to streamflow has to be synthesized. For the St Venant equations the simulated result produces a rating curve.

#### **7.4.1 The truth of the modelled output.**

The truth of the modelled output is an issue for both watershed and stream routing modelling. Both systemic and parametric error is involved in the modelling and involves issues of truth. The simplification always used introduces systemic error. However it will reach a situation where any increase in precision from complexity in modelling is swamped by increased parametric error.

The truth of the modelled output has two components; its pertinence and its success as a model. The pertinence is the meaning of the information produced from the modelling. This is the relevance it has when integrated with other concepts within floodplain management plans. When the modelling is used for a purpose to achieve a goal then it will have a pertinence of 1. This weighting applied through ITFM can be interpreted as 'true' linguistically (see Figure 5.5). Preliminary systematic conceptual definition of relevant hydrological analysis needs to be carried out. This process effectively determines what has pertinence, and so what is worth carrying out analyses for.

The output determined from the hydrologic analysis is a proposition for which a truth value is given. The set of calculated outputs is a set of propositions on which truth constraints are placed. Data measured empirically from the actual events gives reference propositions and forms a set of propositions on which truth constraints are placed. The model's result (a set of simulation propositions "y is F") and the empirical data (a set of reference propositions "y is A") are imprecise and can be considered to be possibility distributions ( $\mu_F$  and  $\mu_A$  respectively) which express the truth constraints placed by the propositions on the values of the variable y. The variable y is the river flow or the river stage. The imprecision represents the parametric error and measurement error of the

model and data collection respectively. The compatibility between  $\mu_F$  and  $\mu_A$  is a truth function and is a measure of the extent of systemic error (see Equation 5.13). The resulting mapping can be interpreted linguistically (see Chapter 5).

#### 7.4.1.1 River flow simulation.

The reference proposition is a fuzzy constraint on the river level over a period. The period is the timestep used in finite element or finite difference numerical analyses. Imprecision arises from the devices measuring river stage and the imprecision in the calculation of river flow from the stage measurements, whether through the use of river cross sections and/or rating curves. Imprecision applies to both simulation and reference propositions. Parametric error in the simulation proposition occurs because of aggradation/degradation that occurs. Also because of the evolution of the physical environment with river cross sectional change, the truthfulness of cross sections and rating curves are always contingent. Systemic error occurs because rating curves are always synthesized. Infinite regress results from trying to overcome all systemic error so eventually some subjective decision about imprecision claiming to take all systemic error into account is required. The 'validation' of it involves determining the truthfulness of it aided from experiments where the water flow can be measured in a way which has a known precision and hence truthfulness, i.e has a high pedigree. (For example with a calibrated weir for small flows.) At some point the validation process becomes socially accepted as a correct definition of the imprecision and uncertainty. It stays socially accepted as long as the results stemming from the information proves itself in the sense of not breaking down trust between the hydrologist and the rest of the community, i.e. if it proves itself to be trustworthy.

However what the 'correct' imprecise cross sections and rating curves are needs to be continually revised. If instead a cross section and rating curve are considered to be a non-contingent entity, it requires that they have a further dimension of imprecision added to account for the cross section changes. The extent of this further imprecision is dependent on how actively the river cross section is changing.

Therefore the reference river flow information is itself synthesised and imprecise. The overall imprecision is defined by the possibility function  $\mu_A$ .

Systemic error can be expected in the simulation producing results making simulation propositions, because of the simplification in the use of the St Venant equations and the discretization into only a limited number of cross sectional changes, which are themselves simplifications and contingent as mentioned above. However as also

mentioned above, the decrease in error resulting from systemic simplification is eventually swamped by parametric error and so the increase in number of cross sectional changes eventually adds no extra information because of parametric imprecision. Pedigree standards evolve for these as well.

Simulation models provide propositions at each time period in the analysis which can be tested for compatibility with actual occurrences. But the purpose of the model is to provide simulation of events that produce a range of propositions that can be accepted as trustworthy as well as truthful; i.e. have a high enough pedigree. Hence there are two issues to consider.

Firstly to determine what range is relevant or pertinent; given in terms of what the model is going to be used for. This is the truth that is established by social legitimation for technical issues because it provides information given by social goals. The range of relevant or pertinent propositions is dependent on what is of interest in floodplain management. Time of arrival, flood peak levels and duration of flood are found to be required in the research here.

Secondly, the model is expected to be acceptable over a range, and it needs to be ascertained over what ranges particular models provide 'true' propositions in terms of being a successful model. Sets of propositions from the time period can be aggregated in some way, or the use of propositions at given time intervals used. From a clarification of what information is relevant, models can be tested as to within what ranges the propositions are compatible with reference propositions. Equation 5.13 can be used to produce a compatibility function for each relevant timestep in the range. Single possibility and necessity values representing the compatibility function can be obtained for each of these through use of Equations 5.14-5.17, 5.26 and 5.27.

If the normalized possibility function (see Equation 5.26)  $\Pi^*(F;A) = 1$  it can be interpreted as meaning that the proposition is mainly correct and so the model is acceptable at that point. If the normalized necessity function (see Equation 5.26)  $N^*(F;A) = 0$  it can be interpreted that it is mainly incorrect. If stronger truth conditions on the success of the model are required then  $N^*(F;A) = 1$  can be used. This makes certain that the results from the model produce sufficient imprecision for it to be assumed that actual results will be encompassed. So if design is carried out according to the relevant bounds given by  $N^*(F;A)$  the goal being designed for will be assured of being achieved. This fulfils the spirit of applying the concept of a *factor of safety*. Whether  $\Pi(F;A)$  or  $N^*(F;A)$  is used is dependent on the purpose for the modelling.

For each interval according to the parameters of time or stage, the above criteria

can be applied and the range over which the model is acceptable determined.

The pertinence of the values which are acceptable is given by whether or not the model covers the pertinent range for which the model is used. If the pertinence is to be calculated for use in decision-making, the values of  $\Pi^*(F;A)$  over the total range being considered form a possibility function  $\Pi(B)$  and a necessity function  $N(B)$  that need to have their compatibility tested with the fuzzy definition of what is the pertinent range, given by  $\Pi(C)$  and  $N(C)$ . Determination of  $\mu_{CP(B;C)}(v)$  or  $\Pi(B;C)$  and  $N(B;C)$  from comparison between possibility functions enables an appreciation of whether or not the model is acceptable for the purpose it is being sought to be used for. But they are not exhaustive of the possible truth values able to be obtained from the information. However the comparison of necessity functions  $N(B)$  and  $N(C)$  between each other and possibility functions cannot be carried out directly, and also it is not appropriate. Never-the-less information is given by such comparisons. The weakest measure of compatibility would be between  $\Pi(B)$  and  $N(C)$  and the strongest measure of compatibility between  $N(B)$  and  $\Pi(C)$ . These hybrids can only be compared by redefining  $N(C)$  and  $N(B)$  so that  $\Pi(D) = \Pi(\text{necessity of } C)$  and  $\Pi(E) = \Pi(\text{necessity of } B)$ . From this six further functions or values can be obtained:  $\mu_{CP(B;D)}$ ,  $\mu_{CP(E;C)}$ ,  $\Pi(E;C)$ ,  $N(E;C)$ ,  $\Pi(B;D)$  and  $N(E;C)$ . There are in total three functions given by the compatibility functions able to be given linguistic interpretation, and six singleton values. The six singleton values form a sequence of measures of strength of compatibility:

$$\Pi(B; D) \geq \Pi(B; C) \geq \Pi(E; C) \geq N(B; D) \geq N(B; C) \geq N(E; C) \quad (7.9)$$

Linguistic interpretations can be made by using the compatibility functions  $\mu_{CP(B;D)}$  and  $\mu_{CP(E;C)}$  and the dialectical relationship of TFM and ITFM (see Chapter 5). The linguistic interpretations and singleton values of the necessity and possibility evaluations are able to be incorporated into decision-making algorithms - the linguistic interpretation in fuzzy logic and the singleton values in approximate reasoning. If models are being compared within a decision-making method their overall values remain unnormalised.

In such decision-making, pertinence in terms of methodological coherence to achieve goals is not the only criterion that needs to be taken into account. Ease of use and cost are also pertinent values to take into account. Aggregation methods to integrate different pertinent values, as with all aggregation, can be carried out in innumerable ways. Some of the ways are reviewed in Chapter 9. However coherence to achieve goals is the most fundamental value, because all others derive their value from it, and so it is *necessary* that it be maximized, given however that the cost *necessary* to make the system

operational is covered by available resources and that it is totally *possible* to use by operators. This can be modelled by three rules:

Rule 1: There are available resources to operationalize the system.

Rule 2: It is totally possible to use by operators.

Rule 3: Maximize the measure of compatibility in terms of pertinence for achievement of goals.

Rules 1 and 2 may be inter-dependent because different operators with different training may cost different amounts to be employed.

Rule 1 is formalised by  $N(\text{resources}; \text{cost})$  and  $\Pi(\text{resources}; \text{cost})$  which form six possible evaluations as in Equation 7.9. Cost to make the system operational and available resources are both fuzzy and can be described by both possibility functions;  $\Pi(\text{cost})$ ,  $\Pi(\text{resources})$ , and necessity functions;  $N(\text{cost})$ ,  $N(\text{resources})$ . The availability of outside funds to make up shortfalls determines what is the appropriate valuation to use.

Rule 2 giving the possibility of being able to be used by operators can be given linguistically.

Rule 3 is formalised by maximizing the valuation given by Equation 7.9 such that it equals 1.

The three rules are applied in sequence. Rule 2 is applied as a truth weighting on the result from rule 1 through TFM. A truth space is produced. From this space rule 3 is applied and a set of best models is defined.

However any number of other decision algorithms could be defined if appropriate. For example it may be important to minimize cost given a certain coherence (pertinence to achieve goals) as precision in results is not of great importance.

If the pertinent range can be defined precisely then a special case of aggregation involving the use of possibility and necessity can be carried out. Over the defined pertinent range, truth functions defining the compatibility can be made so that the use of the information in decision-making takes the uncertainty of the model explicitly into account. The resulting analysis integrates the determination of compatibility and pertinence. A truth value for the model over a range, assuming that the domains of variation of the propositions associated with each interval are independent, can be determined through consideration of the cross product of the set of propositions:

$$\begin{aligned} &\Pi(F_1 \times F_2 \times \dots \times F_n; A_1 \times A_2 \times \dots \times A_n) \\ &= \min(\Pi(F_1; A_1), \Pi(F_2; A_2), \dots, \Pi(F_n; A_n)) \quad (7.10) \end{aligned}$$

$$N(F_1 \times F_2 \times \dots \times F_n; A_1 \times A_2 \times \dots \times A_n) \\ = \min(N(F_1; A_1), N(F_2; A_2), \dots, N(F_n; A_n)) \quad (7.11)$$

It does not require that the events are independent but only that their variations are. Attempts to seek a holistic truth value presupposes that the events are not independent! This aggregation of truth values is however only one possibility along an infinite number of other possible ways. Others are reviewed in Chapter 9.

#### 7.4.1.2 Use for flood warning systems.

One feature of simulation modelling is that it allows for modelling of what happens at a rate faster than the actual event, thus the action of nature can be sped up thus allowing real-time predictions to be made. This feature is what is used in flood warning systems.

Evaluation of the success of the modelling of the hydrological system is used as information as well as the values. Watershed modelling with precipitation hyetograph input and stream routing is used. Inputs exist to give initial condition values. These exist primarily with telemetry stations to relay the information to the hydrologists' office. It includes precipitation data and river stage data. For each initial condition a model exists.

The overall process is to update information about the floodwave as it travels down the catchment. This can be done rigorously by using compatibility measures telling about the truth of the different models. Then the results only have to be aggregated in a risk-averse way.

Firstly the truthfulness (in terms of success) of each model (from each initial condition input) has to be ascertained. The compatibility information needs to be ITFMed onto the simulation propositions about the stage or flows where flood levels are an issue for floodplain management. Each model (i.e each simulation based on different initial conditions) can produce a possibility function of parameters important for making decisions about what to do in the face of possible flooding in the near future. The expected peak (including its expected time of arrival) and the time of arrival of certain thresholds being surpassed are the relevant parameters. The possibility functions of the parameters of values  $s \in S$  that are the output of the  $i$  different models are aggregated together to be risk-averse; i.e. by the use of the max operator on the truth values:

$$\mu_{overall}(s) = \max_i \mu_i(s) \quad (7.12)$$

The value to be used in accordance with the decision rules directing appropriate action is

given by:

$$s^*: \mu_{overall}(s^*) = \sup_{s \in S} \max_i \mu_i(s) \quad (7.13)$$

The truthfulness (which can be interpreted as urgency) of the value  $s^*$  is given by  $\mu_{overall}(s^*)$ .

As a floodwave progresses down a catchment the urgency of the information increases as well as the time of arrival period decreasing. The response to the information using decision rules involves both the parameter's values and its urgency. If a possible flood above a threshold becomes known as  $\Pi(\text{flood}) = 1$  or close to 1, when the time of arrival is not requiring immediate action, then some precautions are required in case one occurs. If the period till arrival means that there have to be actions initiated immediately if contingency plans are to be successfully enacted, then they should be if  $\Pi(\text{flood}) > 0$ .  $\Pi(\text{peak level})$  gives an indication of the expected scope of the flooding and so adds information to ensure that the contingency plans are successful and efficiently carried out. Elaboration on how possible decision rules for flood warning can be included within contingency planning is given in Chapter 10.

## 7.5 FLOOD FREQUENCY CURVES

Flood frequency curves are functions relating river stage or flow to a random variable. They are synthesized so as to be used as information for long-term planning. Traditionally the probability distributions produced enabled technical risk and risk cost benefit analysis (RCBA) to be carried out. Hence they obtain their pertinence from their role in decision-making about planning and design in floodplain management. But their use has been very criticised; for technical reasons in terms of their success as models, and in terms of pertinence.

Firstly the issue of pertinence. Linsley (1986) points out that the designation of the appropriate design flood is problematic. The relevance of, for example, the 100 year Return Period flood is little understood, and is no longer, if it ever was, related to social goals within a coherent decision-making context. Also the use of RCBA assuming long term equilibrium socially and physically is much questioned for both technical and ethical reasons. In response to this a coherent analysis allowing definition of appropriate design floods based on pro-active risk defined by social goals is developed. In Chapter 8 the issue of RCBA for planning is comprehensively reviewed.

Secondly, the technical issue of success in modelling. Because flood frequency curves are statistical models they cannot be developed a priori, however the structure of

the random variable has been attempted to be based on theory to various degrees. Klemes (1989) is critical of the statistical basis per se because of the assumptions associated. He criticises the ergodic assumption and the stationarity assumption. Stationarity assumes that the random variable is constant and hence so are the hydrological processes creating the events.

The ergodic assumption means that statistical information of historical events is representative of any other set of events, including the present and the future. Non-stationarity of hydrological events is a sufficient condition for non-ergodicity, though not a necessary condition, and so even the expected non-stationarity of hydrological events means that statistical data cannot logically be assumed to be indicative of what is the future random distribution of hydrological events. Even though the fluctuations due to yearly and sunspot cycles may legitimately be insignificant because they are repeated into the future, geomorphic evolution is a unique trajectory.

Geomorphological processes stem from the movement of the earth's plates which means that there is an inherent non-reversible and changing aspect in the events producing floods, even though precipitation may be able to be modelled ergodically. However, precipitation stationarity will be affected by regional de/reforestation and global change in weather patterns. The issue is whether or not the changes are to such an extent that the assumption of ergodicity is not appropriate. This is a matter of pertinence and decomposed into a question of timescales. Theoretically ergodicity is not valid but for modelling for specified goals it may be appropriate. Klemes raised valid criticism but did not raise the issue of pertinence which also makes his criticism 'impertinent'. Criteria for determining what conditions allow ergodicity to be accepted are addressed below. Suffice to say here that much of the debate is resolved when the 'requirement' for precise results is overcome.

Davies and Hall (1992) point out a more serious limitation. Because of very different physical processes in the watershed and streamflow, different random variables occur for different ranges of stage. An example is how debris damming streams beyond a threshold collapses and so sudden jumps in stage occur. Because of this, outlier values in distributions should be taken seriously, but because of the way flood frequency curves are regressed there is no way to do so. The problem exists because, as for example Pilgrim (1986) argues, single precise results are 'required'.

Even though matters of ergodicity and stationarity can be resolved by defining appropriate time scales a technical issue related to pertinence remains. As Klemes (1989) puts it, the precise probabilities defined are 'improbable probabilities'. At the most



fundamental level the definition of precise models is a logical absurdity as shown in Chapter 5. However if a phenomenological interpretation is made then they can be taken to be idealisations. But as Doodge (1986) points out, the hydrological system is a 'middle number system' and so the uncertainty of the idealisation is very great! So it is problematic to construct even phenomenological models.

McKerchar and Pearson (1989) give a standard error for the determination of flood events using the Regional Flood Estimation method for rivers in Aotearoa/New Zealand where the probability of exceedance of 0.01 is  $\pm 17\%$ . Young (1990) gives similar results from a thorough analysis of the issue reviewing the available regression techniques. He concludes with an estimate of  $\pm 25\%$  with a minimum value of  $\pm 15\%$  for some of the best gauged catchments in Aotearoa/New Zealand. He also claims that to make an 'objective' estimate of a flood with such a probability of exceedance would require 1000 years of data. However he failed to define what he meant by an 'objective estimate'. As long as imprecision is explicitly defined then it is surely objective. What Young is implying, as shown by his later arguments for the use of subjective probability, is that objective information does not allow decisions to be logically made within existing decision-making procedures.

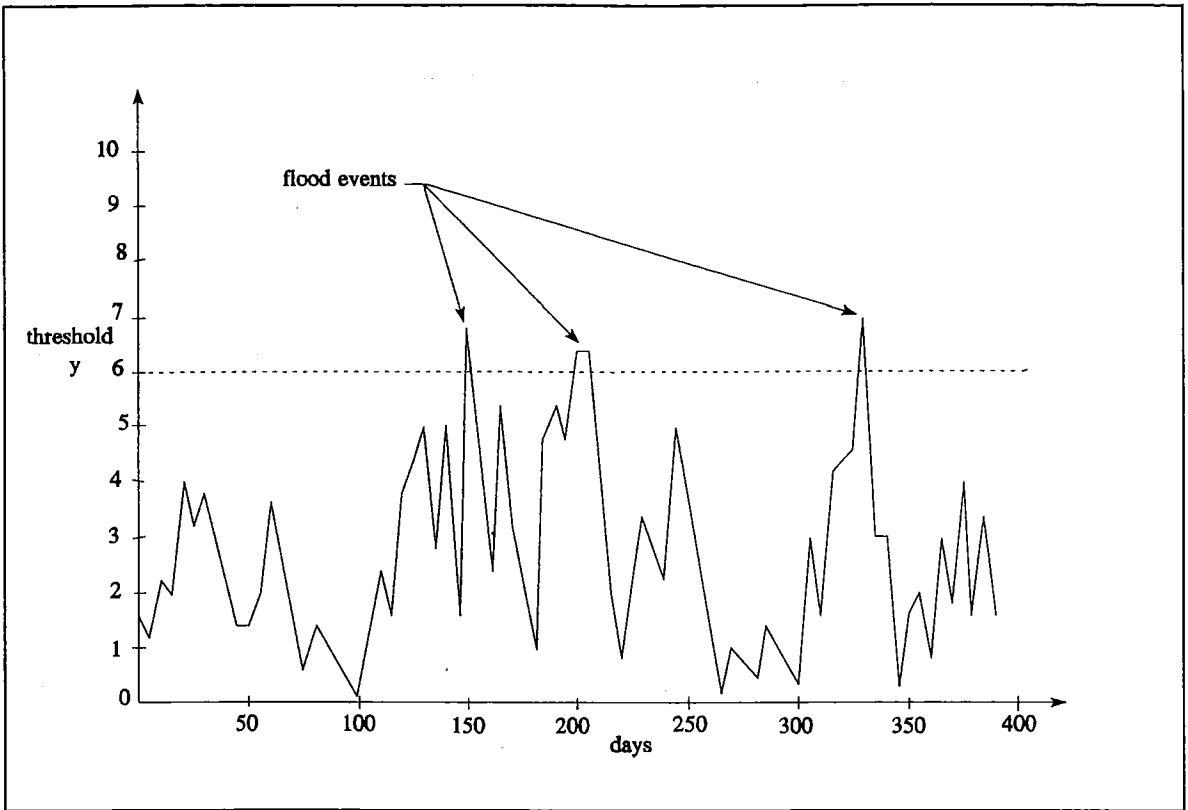
Beven (1993) takes a different tack and argues that any attempt to define precise data is prophecy. This can be taken further and the argument made that the reasons for doing so are because the existing decision procedures are not able to use imprecise data. As already mentioned, to understand this process requires us to see the context in which the 'prophecies' are used; i.e. what decision-making rules they legitimate and structural power relations they help maintain. They are used in the context of the use of economic models as decision-making tools that are acting as self-fulfilling prophecies to support a monocultural competitive market institution (see Chapter 8). So it is not surprising that for 'social realism' in the sense of social integration it is argued that precise results are required for decision-making (e.g. by Pilgrim 1986 and Young 1990). Young recommends the use of subjective probability, admitting objective imprecision, so that decision-making using precise results can still be carried out. What Young is naively or implicitly arguing for is the continuing of elite decision-making by hydrologists even though there is no technical knowledge that they are basing their decisions on. Young is implicitly suggesting that the existing power relations involving hydrologists (engineers) marketing their 'services' can and should be maintained. In Chapter 8 it is also explored how the precise results produced are also required to enable the market institution to be maintained and created through the use of exact cost benefit analyses (CBA).

Below a different approach is taken that starts with the objective uncertainty that Young explored, but instead of forgetting it so as to prophesy to socially integrate, it is explored how instead to use the actual information present in helping to create social goals as part of participatory democracy to explicitly socially construct self-fulfilling prophecies in the attempt to avoid coercive ideology. The seeking to improve structural power relations extends Beven (1993) so as to put the analysis into context, and hence allow the understanding of their pertinence. The consequence is that trust is sought to be gained between members of the community rather than the abuse of power through elite claims. The imprecision can be used within Expert System decision-models outlining social goals defined through public participation. The process to achieve this is developed in the remainder of this chapter and in Chapters 8. The remainder of this chapter develops the pertinent hydrological hard system analysis required for the overall process.

Practicality has also to be addressed. If no calculus exists for determination of realistic information then idealizations are required along with factors of safety. In effect hydrology has made and used idealisations without the implementation of the necessary factors of safety. To avoid this 'temptation' brought about by ideological naivety, practical methods through the development of feasible methods to determine realistic imprecise flood frequency curves are developed. They are developed in the context of, and involving an extension of, the Regional Flood Estimation method that Aotearoa/New Zealand has available.

### **7.5.1 A stochastic model.**

Flood events have to be defined. This does not involve a distinction between baseflow and non-baseflow. Baseflow is a physically defined feature. Floods by comparison require definition in reference to a social context. A threshold is one way to define what are floods. Once a threshold is defined, individual flood events and their magnitude can be defined (see Figure 7.5). A Poisson process of occurrence of flood events and a -ve exponential function modelling the magnitude of events was postulated as an adequate model. As a first step toward testing the model a Monte Carlo simulation was carried out. Two random generators sampling from -ve exponential density functions were used to model precipitation. This modelling was considered acceptable because of previous testing of the hypothesis that precipitation can be modelled thus. To model the effect of watershed integration the precipitation was modelled as accumulating in the stream as a triangular event of streamflow with a constant infiltration rate able to be defined. The precipitation parameters were those determined by Morrison (1988) for



**Figure 7.5;** Definition of flood events.

Christchurch rainfall, i.e. an average time between 'storm' events of 2.3 days with an average precipitation for each 'storm' of 6mm. The resulting streamflow events were summed (n) for each time interval. Computer code for the simulation is given in Appendix A.2.

The Monte Carlo simulation was run for a simulated period of 1000 years. A typical resulting simulated streamflow is given by Figure 7.5. An example of a simulated flood frequency output is given in Figure 7.6.

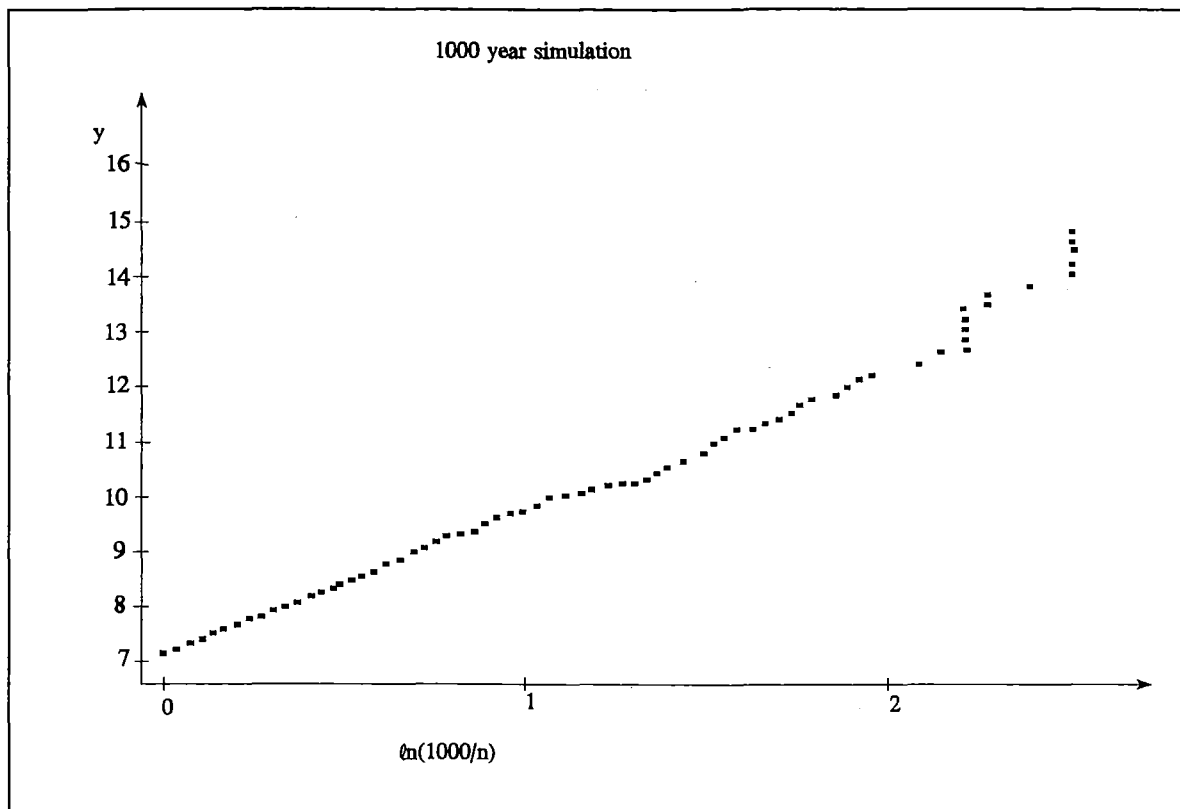
Consider that the result from the plot in Figure 7.6 is linear, i.e. let:

$$y = m \ln\left(\frac{N}{n}\right) + c \quad (7.14)$$

where N is the number of years simulated.

$$\begin{aligned} \Rightarrow \frac{(y-c)}{m} &= \ln N - \ln n \\ \Rightarrow n &= e^{\ln N - \frac{y-c}{m}} \quad (7.15) \end{aligned}$$

Also assume that:



**Figure 7.6;** Simulated flood frequency curve.

$$\int_0^{\infty} P(y | \text{flood event occurs}) dy \approx 1$$

because  $N$  is sufficiently large that  $P(\text{flood event occurs}) \approx 1$ . Now let:

$$\begin{aligned} P(y) &= kn \\ &= ke^{\ln N - \frac{y-c}{m}} \end{aligned} \quad (7.16)$$

$$\begin{aligned} \Rightarrow \int_0^{\infty} ke^{\ln N - \frac{y-c}{m}} dy &= 1 \\ \Rightarrow mke^{\ln N + \frac{c}{m}} &= 1 \\ \Rightarrow k &= \frac{1}{m} e^{-\ln N + \frac{c}{m}} \end{aligned} \quad (7.17)$$

Substituting into Equation 7.16 gives:

$$P(y | \text{flood event occurs}) = \frac{1}{m} e^{\frac{y}{m}} \quad (7.18)$$

Now, the Return Period  $T_r$ :

$$T_r = \frac{1}{P(Y \geq y)} \approx \frac{1}{P(Y \geq y | \text{flood event occurs})}$$

and:

$$\begin{aligned} P(Y \geq y | \text{flood event occurs}) &= \int_y^{\infty} \frac{1}{m} e^{-\frac{Y}{m}} dY \\ &= e^{-\frac{y}{m}} \quad (7.18) \end{aligned}$$

Assuming a Poisson process the relationship between a threshold given by a value of  $y$  and the Exceedance distribution is given by:

$$\begin{aligned} P(Y \geq y | \text{an event occurs}) &= \int_y^{\infty} \beta e^{-\beta Y} dY \\ &= e^{-\beta y} \quad (7.19) \end{aligned}$$

$$\begin{aligned} &= e^{-\frac{y}{m}} \quad (7.18) \\ \Rightarrow \beta &= \frac{1}{m} \quad (7.20) \end{aligned}$$

Also:

$$P(Y \geq y | \text{an event occurs}) = \frac{P(Y \geq y \cap \text{an event occurs})}{P(\text{an event occurs})}$$

and because  $N$  is large with  $P(\text{an event occurs}) \approx 1$ :

$$P(Y \geq y | \text{an event occurs}) \approx P(Y \geq y \cap \text{an event occurs})$$

Now,  $P(Y \geq y \cap \text{an event occurs})$  is given for a period, say  $T$ . If the value of  $y$  is large and the number of events in the period  $T$  is large then  $P(Y \geq y \cap \text{an event occurs})$  is an Extreme Value distribution (see Section 7.5.2.1).

Let:

$$y_T = -\ln(-\ln(1 - \frac{1}{T_r})) \quad (7.21)$$

$$= -\ln(-\ln(1 - e^{-\frac{y}{m}})) \quad (7.22)$$

from Equation 7.18. Equation 7.21 defines the Gumbel reduced variable  $y_T$  which is used in the analysis of the Extreme Value function. Given in its most general form (GEV) it

has three parameters  $\omega, k, u$ :

$$P(Y \leq y) = e^{1 - (1 - \frac{k(y-u)}{\omega})^{\frac{1}{k}}} \quad (7.23)$$

The limit of equation 7.23 as  $k \rightarrow 0$  is the Extreme Value type 1 (EV1) distribution given by:

$$P(Y \leq y) = e^{-e^{-\frac{y-u}{\omega}}} \quad (7.24)$$

which produces a straight line when plotted with the Gumbel reduced variable  $y_T$ .

Whether  $k < 0$  or  $k > 0$  produces respectively EV2 and EV3 distributions.

The plotting of Equation 7.21 with the data from the simulation in Figure 7.6 regresses close to a linear distribution, and is not significantly non-linear. Therefore there is no reason to not model the results according to an EV1 distribution. Pragmatically so as to produce pertinent knowledge it is appropriate.

Now let  $P(\text{a flood event occurs})$  in a short period  $\Delta t$  equal  $\theta$  where  $\theta \cdot T =$  the mean number of a flood events in the period  $T$ . Therefore the probability of occurrence of  $N$  flood events in a period  $T$  is given by Equation 7.4 replacing  $\lambda$  with  $\theta$ .

However the probability of a flood occurrence defined as occurring above a particular threshold  $y$  is given by:

$$P(Y \geq y | \text{an event occurs}) = P(\text{an event occurs}) \cdot P(Y \geq y) \\ = \theta T e^{-\beta y} \quad (7.25)$$

substituting into Equation 7.4 gives:

$$P(N | \text{threshold} = y) = \frac{\theta T^N e^{-\beta y} e^{-\theta T e^{-\beta y}}}{n!} \quad (7.26)$$

A useful further result is that the probability of at least one flood event occurring above a level  $y$  during a period  $T$  is given by:

$$P(N \geq 1) = 1 - \theta T e^{-\beta y} \quad (7.27)$$

$\beta$  can be obtained directly from regressions of  $m$ . The variance of  $m$  can be used to synthesize a possibility function of the parameter  $\beta$  according to Figure 5.4. Calculation of  $\theta$  has to be deduced from regressions of the synthesized flood data, or from analysis of regressions of Extreme value distributions directly onto streamflow data (see Section 7.5.3). Regressions of the simulated flood data can theoretically be successful

through the use of a Gamma distribution because each flood event is the aggregation of several random exponential distributions. This was found to be the case. It was also found to be the case that the shape parameter which is a measure of the number of Exponential distributions that are added was found to be dependent on the threshold chosen, as expected. Using the relationship between Exponential and Gamma distributions and the Method of Moments to fit sample parameters enables determination of the equivalent Poisson process valued  $\theta$  parameter to be carried out straightforwardly. Because an Exponential distribution is a special case of a Gamma distribution where the shape parameter equals 1, setting the shape parameter to 1 enables the calculation of the equivalent value of  $\theta$ . For a Gamma distribution,  $E(y)=k/\theta$ . Setting  $k=1$  gives simply that the equivalent value of  $\theta=1/E(y)$ .

Equation 7.27 can be used for risk analysis of floods above a certain level within a design period. Equation 7.26 can be used within economic analysis of expected damage. Damage due to flooding can be given as a function of river stage, i.e. flood magnitude. This is developed in Chapter 8.

Both  $\theta$  and  $\beta$  are imprecise. When the imprecision is determined, and through the use of a possibility function taking  $\alpha$ -level cuts, imprecise results for the deduced values of  $\theta$  and  $\beta$  can be made. However transformations are required so the equations are isotonic.

For Equation 7.26 there are four possibilities given by whether or not  $T$  is precise or imprecise and whether or not  $y$  is precise or imprecise. Firstly:

$$\text{let } \beta_* = -\beta \Rightarrow \mu_{\beta_*}(\beta) = \mu_{\beta}(-\beta) \quad (7.28)$$

If  $T$  is imprecise then:

$$\text{let } T_* = T^N \Rightarrow \mu_{T_*}(T) = \mu_T(T^N) \quad (7.29)$$

If  $T$  is precise then:

$$\text{let } \theta_* = T^N \theta \Rightarrow \mu_{\theta_*}(\theta) = \mu_{\theta}(\theta/T^N) \quad (7.30)$$

$$\text{and let } \theta_T = T\theta \Rightarrow \mu_{\theta_T}(\theta) = \mu_{\theta}(\theta/T) \quad (7.31)$$

If  $y$  is precise then:

$$\text{let } C_* = -e^{y\beta_*} \Rightarrow \mu_{C_*}(\beta_*) = \mu_{\beta_*}(-\ln(\beta_*/y)) \quad (7.32)$$

$$\text{and let } D_* = (1/N!)e^{y\beta_*} \Rightarrow \mu_{D_*}(\beta_*) = \mu_{\beta_*}(N!\ln(\beta_*/y)) \quad (7.33)$$

If  $y$  is imprecise then:

$$\text{let } C_* = -C \text{ where } C = e^{y\beta_*} \Rightarrow \mu_{C_*}(C) = \mu_C(-C) \quad (7.34)$$

$$\text{and let } D_* = (1/N!)C \Rightarrow \mu_{D_*}(C) = \mu_C(N!C) \quad (7.35)$$

Therefore there are four possible isotonic functions:

If  $T$  and  $y$  are both precise:

$$P(N|y \text{ is the threshold}) = \theta_* D_* e^{\theta_* C_*} \quad (7.36)$$

where  $D_*$  is given by Equation 7.33 and  $C_*$  is given by Equation 7.32.

If  $T$  is precise and  $y$  is imprecise:

$$P(N|y \text{ is the threshold}) = \theta_* D_* e^{\theta_* C_*}$$

where  $D_*$  is given by Equation 7.35 and  $C_*$  is given by Equation 7.34.

If  $T$  is imprecise and  $y$  is precise:

$$P(N|y \text{ is the threshold}) = \theta T_* D_* e^{T \theta C_*} \quad (7.37)$$

where  $D_*$  is given by Equation 7.33 and  $C_*$  is given by Equation 7.32.

If  $T$  is imprecise and  $y$  is imprecise:

$$P(N|y \text{ is the threshold}) = \theta T_* D_* e^{T \theta C_*}$$

where  $D_*$  is given by Equation 7.35 and  $C_*$  is given by Equation 7.34.

For Equation 7.32:

If  $T$  is imprecise and  $y$  is precise:

$$P(N \geq 1) = 1 + \theta_* C_* \quad (7.53)$$

where  $C_*$  is given by Equation 7.35.

If  $T$  is imprecise and  $y$  is precise:

$$P(N \geq 1) = 1 + \theta T C_* \quad (7.38)$$

where  $C_*$  is given by Equation 7.32.

If  $T$  is precise and  $y$  is imprecise:

$$P(N \geq 1) = 1 + \theta_* C_*$$

where  $C_*$  is given by Equation 7.33.

If  $T$  is imprecise and  $y$  is imprecise:

$$P(N \geq 1) = 1 + \theta T C_*$$

where  $C_*$  is given by Equation 7.34.

Consideration of pertinence remains. The pertinence comes from whether or not the particular model is the most appropriate one. As it is the only one known that enables the solution of Equations 7.26 and 7.27, it must have high pertinence as long as the equations are useful. They are useful to the extent that the Poisson model is useful. However alternative ways to determine  $\theta$  and  $\beta$  exist and are developed below. Two alternative ways are given. The stochastic model developed is dependent on the ability to determine directly the stochastic parameters through sampling of a continuous streamflow. This is not straightforward and so the alternative methods based on asymptotic theory developed below may be better.



### 7.5.2 Statistics of extremes.

Traditionally, for practical purposes, measurement of river flow has been carried out by measuring the maximum river flow level over a period, usually one year. This method does not explicitly define individual 'flood' events. A stochastic model is not employed. Rather it is based on the statistics of extremes. The rationale for it appears to be that information on extreme events over a period of typically one year is adequate information as it enables the Return Period to be defined, and Risk Cost benefit Analysis to be carried out which considers annual expected damages.

Todorovic and Zelenhasic (1970), Revfeim (1983) and Karlsson and Haimes (1988) have all given good reviews of the development of this theory for flood events.

#### 7.5.2.1 Asymptotic theory.

The standard approach to extreme value theory has been based on the asymptotic theory that the determination of extreme values from underlying distribution functions will converge to three particular forms depending on the shape of tail of the underlying functions, as the number of events from these distributions  $n \rightarrow \infty$ . The three such forms are given the names type I, type II and type III. Tails that are of a -ve exponential form give rise to type I. An attempt to parameterize these has been made in the definition of the GEV, thus giving rise to three types of GEV with the type 1 giving rise to the EV1.

The EV1 equation is also called the Gumbel equation. It has been used extensively because of its empirical fit for measurement of maximum flood levels in a given period interval. The theoretical basis argued for by McKerchar and Pearson (1989) is based on the intuitively reasonable assumption that the underlying distribution of flood magnitudes has a -ve exponential function.

The Monte Carlo model could be used to explore the relationship between the resulting GEV distribution and the effect of the type of integration of precipitation and infiltration that is modelled. This could be further attempted to be related to physical characteristics of catchments using empirical data. However this interesting field is beyond the purpose of the research here which is aimed at establishing pertinent hydrological parameters for floodplain management.

It is a well known result (e.g. Revfiem 1983, McKerchar and Pearson 1989) that the expected value for the maximum event in T years for an EV1 distribution is given by:

$$E_E(y) = u + \omega y_T \quad (7.34)$$

The use of data gained from maximum flood levels in a set period, usually 1 year

(allowing the assumption of  $n \rightarrow \infty$  to be made), has traditionally been carried out because of ease of data reduction. This may change because computer storage should allow direct analysis according to a stochastic model using thresholds. Never-the-less, annual maxima are the predominant data reduction carried out. But the assumptions are questionable. The number of 'flood' events may not be large enough for the asymptotic assumption to be made even though  $n > 1$ .

McKerchar and Pearson (1989) have tested many sites in Aotearoa/New Zealand and found that in some cases the determining of the maximum over a two year period and sometimes a three year period will enable an EV1 distribution to be accepted where it could not when a one year period was used. Doing this of course however decreases the sample size by half or a factor of three.

### 7.5.2.2 A stochastic derivation of extreme values.

The use of a stochastic basis for extreme values was first suggested by Todorovic and Zelenhasic (1970). Distributions for both the maximum flood peak exceedance in a period, and risk associated with exceedance in a period were derived but have not been used. Equation 7.27 is simpler than the equation derived by Todorovic and Zelenhasic for risk of exceedance but along similar lines. Todorovic and Zelenhasic summed up expected yearly extremes rather than considering all 'flood' events as has been carried out for the derivation of Equation 7.27.

Revfiem (1983) approached the situation similarly to Todorovic and Zelenhasic but in reference to rainfall extremes and compared the parameters resulting to those gained by the use of the Gumbel method. The mathematics does not change. Revfiem shows how the distribution function for the maximum event in a period T is given by:

$$P_E(Y \leq y) = \frac{e^{-\theta T(1-F(y))} - e^{-\theta T}}{1 - e^{-\theta T}} \quad (7.35)$$

where  $F(y)$  is the distribution function:

$$P(Y \leq y | \text{an event occurs}) = 1 - e^{-\theta T}$$

Making this substitution Revfiem determined the mean assuming the n was large, giving:

$$E_E(y) = \frac{1}{\beta (\ln \theta + \gamma \ln T)} \quad (7.36)$$

where  $\gamma$  = Euler's constant = 0.57722...

Completing the substitution into Equation 7.35 gives the distribution function for the expected maximum event in a period T:

$$P_E(Y \leq y) \approx \frac{e^{-\theta T e^{-\beta y}} - e^{-\theta T}}{1 - e^{-\theta T}} \quad (7.37)$$

As yet the derivation given by Equation 7.37, left unarticulated by Revfiem (1983), has not been used in floodplain management decision-making to my knowledge. However it potentially can make a contribution. It fills an impasse existing at present outlined by Linsley (1986) about what is the appropriate design flood level. Equation 7.37 enables a coherent risk analysis decision to be made in relation to the expected maximum event in a given pertinent design period. So if a risk level of say 0.01 is socially defined as appropriate then the design of flood protection for the design period for the flood protection can proceed. Traditionally completely incoherently as explained in Chapter 6, an acceptable risk level  $P_r=0.01$  has been associated with a 100 year return period flood; i.e. the risk that a flood of given magnitude will occur with the probability of 0.01 in every year! It is well known (e.g. Young and Davies 1989, and Davies and Hall 1992) that such a criterion in a design period of say  $m=25$  years will have a probability of 'failure' given by:

$$1-(1-P_r)^m \quad (7.38)$$

i.e.

$$1-(1-0.01)^{25} = 0.22$$

i.e. nearly a chance of 1 in 4. Such a risk has quite possibly a very different meaning to society than the idea of a 100 year flood.

In response to the traditional incoherence, Young and Davies (1989) suggested that floodplain management decisions be based on probable maximum floods (PMF). Such an approach has been implemented by Griffiths et al. (1991). Yet this is effectively assuming that the design period is infinite, and so is inefficient (and incoherent if this is not recognised). There is no necessity for the PMF to be planned for even though it does provide a sufficient solution to achieve the goal. The use of Equation 7.37 will allow the meaning of a certain risk over the design period to be implemented efficiently.

The EV1 and stochastic models can be compared by comparing Equations 7.34 and 7.36. Revfiem (1983) has pointed out that if the period of 1 year is considered, i.e.  $T=1$ , then from the stochastic model:

$$P_E(Y \leq y) = 1/\beta(\ln \theta + \gamma) \quad (7.39)$$

Also the GEV method for a type 1 distribution the first moment by the use of the Probability Weighted Moments is given by (McKerchar and Pearson 1989):

$$PWM_0 = u + \gamma\omega \quad (7.40)$$

and for  $T=1$ :

$$PWM_0 = E_E(y) \quad (7.41)$$

$$\therefore E_E(y) = u + \gamma\omega \quad (7.42)$$

Therefore comparing Equations 7.39 and 7.42 gives:

$$\beta = 1/\omega \quad (7.43)$$

$$\theta = e^{u/\omega} \quad (7.44)$$

These results enable Equations 7.26 and 7.27 to be solved using extreme value theory. Revfiem (1983) has also pointed out that for any value of  $T$  the stochastic model uses  $\gamma + \ln T$  instead of  $y_T$  as is done in the GEV method. Therefore with increasing  $T$ ,  $y_T \approx \ln T$ , therefore the EV1 method has a constant deficit of  $\gamma/\beta$ . Further that the stochastic model is better behaved than the EV1 method because using  $y_T$  results in  $E_E(y)$  being less for  $T=2$  than for  $T=1$ . It can be concluded that the attempted parameterization of extremes through the use of the EV1 equation is imperfect and that a stochastic model, being even more physically based than the GEV method, may be superior. Pragmatically it may not be pertinent however. The advantage of the stochastic method that is however pertinent is that it enables the distribution of the expected maximum event in a period to be determined (i.e. that given by Equation 7.38) whereas the EV1 method cannot unless it is used to synthesise values of  $\theta$  and  $\beta$  for use in the stochastic model. This is where it is most pertinent.

Equation 7.37 is used to determine the expected maximum flood in a given period with a particular risk. The imprecisions in the values of the parameters  $\beta$  and  $\theta$  need to be taken into account. The possibility functions describing the two parameters with the use of  $\alpha$ -level cuts enables the resulting fuzzy result for the fuzzy maximum expected flood to be obtained. Never-the-less Equation 7.37 has to be transformed so as to be isotonic.

$T$  can be precise or imprecise and  $y$  can be precise or imprecise. If  $T$  is precise:

$$\text{let } F = -e^{-\theta T} \Rightarrow \mu_F(\theta) = \mu_\theta(-\ln[-\theta/T]) \quad (7.45)$$

$$\text{and let } G = -\theta T \Rightarrow \mu_G(\theta) = \mu_\theta(-\theta/T) \quad (7.46)$$

$$\text{and let } F_* = 1/(1+F) \Rightarrow \mu_{F_*}(F) = \mu_F(1/[1+F]) \quad (7.47)$$

If  $T$  is imprecise:

$$\text{let } \theta_1 = -\theta \Rightarrow \mu_{\theta_1}(\theta) = \mu_{\theta}(-\theta) \quad (7.48)$$

$$\text{and let } F = -k \text{ where } k = e^{\theta_1 T} \Rightarrow \mu_F(k) = \mu_k(-k)$$

$$\text{and let } F_* = 1/(1+F) \Rightarrow \mu_{F_*}(F) = \mu_F(1/[1+F])$$

If  $y$  is precise:

$$\text{let } H = e^{-\beta y} \Rightarrow \mu_H(\beta) = \mu_{\beta}(\ln[-\beta/y]) \quad (7.49)$$

If  $y$  is imprecise:

$$\text{let } \beta_1 = -\beta \Rightarrow \mu_{\beta_1}(\beta) = \mu_{\beta}(-\beta) \quad (7.50)$$

So four possible isotonic functions occur:

If  $T$  is precise and  $y$  is precise:

$$P_E(Y \leq y) = (e^{GH} + F)F_*$$

If  $T$  is precise and  $y$  is imprecise:

$$P_E(Y \leq y) = [\exp(Ge^{\beta y}) + F]F_* \quad (7.51)$$

If  $T$  is imprecise and  $y$  is precise:

$$P_E(Y \leq y) = (e^{\theta_1 TH} + F)F_* \quad (7.52)$$

If  $T$  is imprecise and  $y$  is imprecise:

$$P_E(Y \leq y) = [\exp(\theta_1 T e^{\beta y}) + F]F_* \quad (7.53)$$

However it is more direct to use Equation 7.37 to solve for the domain of possible probable maximum floods, by considering the acceptable fuzzy risk of exceedance given by say  $\mu_R$  and comparing it with the fuzzy risk of exceedance  $\mu_{Pr}(Y \leq y)$  given by Equation 7.37. Acceptable risk can be defined by a possibility function  $\mu_R$ . Then the compatibility between  $\mu_{Pr}(Y \leq y)$  and  $\mu_R$  can be carried out and integrated into decision-making algorithms. The determination of what are the appropriate compatibility measures follows from those raised in Section 7.4.

### 7.5.3 Regional Flood Estimation Method.

Where there is little information specific to a catchment this method enables the determination of flood frequency curves using a GEV parameterization of extreme values. McKerchar and Pearson (1989) give a straightforward description of the technique and application for Aotearoa/New Zealand. A non-dimensional representation of a flood with a probability of exceedance of 0.01 (a '100 year flood') ( $q_{100}$ ) is derived. Estimates for  $q_{100}$  are obtained by regressing data onto a GEV distribution while aiming to obtain an EV1 distribution. Then the estimate for  $q_{100}$  enables values for other size floods in catchments, which may not have the data to be regressed to form a flood frequency curve, to be calculated.  $q_{100}$  is related to specific flood estimates through the mean expected flood  $E(Q)$ :

$$Q_{100} = E(Q)q_{100} \quad (7.54)$$

For return periods other than 100 years:

$$Q_T = E(Q)[x_T + (1-x_T)q_{100}] \quad (7.55)$$

$$\text{where } x_T = (y_{100} - y_T)/(y_{100} - \gamma) \quad (7.56)$$

with  $y_{100}$  and  $y_T$  being given by Equation 7.39.

Estimates for  $E(Q)$  have to be obtained for specific catchments using:

$$E(Q) = k_m A^{0.8} \quad (7.57)$$

where  $A$  is the catchment area and  $k_m$  is given for regions gained from 'regressions'.

McKerchar and Pearson (1989) in calculating error for  $E(Q)$ , which were found to be normally distributed, found a standard error of  $\pm 22\%$  for 95% of the catchments in Aotearoa/ New Zealand. This can be used as being indicative of the minimum degree of uncertainty possible to be achieved.

As mentioned above the overall standard error for  $q_{100}$  was found by McKerchar and Pearson to be 17%. Both this uncertainty and the uncertainty for  $E(Q)$  have to be used in calculations using the Regional Flood Estimation method.

These uncertainties can be turned into possibility functions describing imprecision by using the intuitive technique outlined in Chapter 5 using the feature of the error being normally distributed.

What is of interest here is how the method can be used to determine the parameters needed to solve Equations 7.26, 7.27 and 7.37 for use in economic analysis, as this is pertinent truth for hydrologic 'truth' for floodplain management.

Where there is little information the determination of  $\theta$  and  $\beta$  through analysis of streamflow data using different thresholds is not possible. But where there are some data in the form of annual maximum flows the Regional Flood Estimation method is a practical, straightforward and versatile method to do so and so has high pedigree.

A straightforward way to calculate nearly unbiased estimates for the parameters for the EV1 distribution is given by the method of Probability Weighted Moments mentioned above using annual maximum flow data. McKerchar and Pearson (1989) outline a method of estimating parameters using the GEV method. For the EV1 it is given by:

$$\omega = \frac{2 P W M_1 - P W M_0}{\ln 2} \quad (7.58)$$

$$u = P W M_0 - \gamma \omega \quad (7.59)$$

where given an ordered sequence:  $y_1 < y_2 < y_3 \dots y_j \dots y_n$

$$PWM_0 = \sum_{j=1}^n \frac{y_j}{n} \quad (7.60)$$

$$PWM_1 = \sum_{j=1}^n \frac{(j-1) y_j}{n(n-1)} \quad (7.61)$$

If estimates are unbiased the Cramer-Rao inequality (Equation 7.62) can be used to approximate the variance of the estimates (Hines and Montgomery 1980). Using the near-unbiased characteristic of the Probability Weighted Moments method allows estimates gained from Equations 7.58-7.61 to be used. Otherwise the more complicated task of solving a difficult set of two equations using the Maximum Likelihood Method is required, e.g. Linsley et al. (1982).

The Cramer-Rao inequality for the parameter  $v$  is given by:

$$v_s - Z_{\frac{\eta}{2}} \sqrt{V(X_s)} \leq v \leq v_s + Z_{\frac{\eta}{2}} \sqrt{V(X_s)} \quad (7.62)$$

where  $Z_{\eta/2}$  is the standard Normal statistic with  $100-\eta$  being the confidence level, and the variance occurring in the random function  $f(X,v)$  is given by:

$$V(X, v) \approx \frac{1}{nE\left[\frac{d}{du} \ln f(X, v)\right]^2} \quad (7.63)$$

For the EV1 probability distribution the variance of the estimates for  $\omega$  and  $u$  are required. The Probability function of the EV1 is:

$$f_E(y) = \frac{1}{\omega} e^{-\frac{1}{\omega}(y-u)} - e^{-\frac{1}{\omega}(y-u)} \quad (7.64)$$

$$\Rightarrow \ln f_E(y) = -\ln \omega - \frac{1}{\omega}(y-u) - e^{-\frac{1}{\omega}(y-u)}$$

$\therefore$  for  $V(u)$ :

$$\frac{d}{du} \ln f_E(y) = \frac{1}{\omega} - \frac{1}{\omega} e^{-\frac{1}{\omega}(y-u)}$$

$$\Rightarrow \left(\frac{d}{du} \ln f_E(y)\right)^2 = \frac{1}{\omega^2} (1 + e^{-\frac{2}{\omega}(y-u)} - 2e^{-\frac{1}{\omega}(y-u)})$$

$$\therefore E\left(\frac{d}{du} \ln f_E(y)\right)^2 = \frac{1}{\omega^2} (1 + e^{\frac{2u}{\omega}} E(e^{-\frac{2}{\omega y}}) - 2e^{\frac{u}{\omega}} E(e^{-\frac{1}{\omega}}))$$

The terms  $E(e^{-2/\alpha y})$  and  $E(e^{-1/\alpha})$  are moment generating functions. Expanding them as a power series, only keeping terms containing the coefficient given by  $1/\omega$  to an order of power less than 3, and using the inequality given by Equation 7.36 for  $E_E(y)$ , here as  $E(y)$ , gives:

$$E\left(\frac{d}{du} \ln f_{Ey}\right)^2 \approx \frac{1}{\omega^2} \left(1 + e^{\frac{2u}{\omega}} \left(1 - \frac{2u}{\omega} - 2\gamma\right) + 2e^{\frac{u}{\omega}} \left(\frac{u}{\omega} + \gamma - 1\right)\right)$$

$$\therefore V(y, u) \approx \frac{\omega^2}{n \left(1 + e^{\frac{2u}{\omega}} \left(1 - \frac{2u}{\omega} - 2\gamma\right) + 2e^{\frac{u}{\omega}} \left(\frac{u}{\omega} + \gamma - 1\right)\right)} \quad (7.65)$$

Similarly for  $V(\alpha)$ :

$$\frac{d}{d\omega} \ln f_{Ey} \approx -\frac{1}{\omega} + \frac{1}{\omega^2} (y-u) \left(1 - e^{-\frac{1}{\omega}(y-u)}\right)$$

$$\Rightarrow \left(\frac{d}{d\omega} \ln f_{Ey}\right)^2 \approx \frac{1}{\omega^2} \left(2 - 2(y-u)e^{-\frac{1}{\omega}} + e^{-\frac{2}{\omega}(y-u)}\right)$$

and:

$$E\left(\frac{d}{d\omega} \ln f_{Ey}\right)^2 \approx \frac{-2u\gamma}{\omega} + \frac{1}{\omega^2} \left(1 - u^2 - 2ue^{\frac{u}{\omega}} + 2u^2\gamma \left(e^{\frac{u}{\omega}} - e^{\frac{2u}{\omega}} - 2\gamma\right)\right)$$

$$\therefore V(y, \omega) \approx \frac{1}{n \left(\frac{-2u}{\omega} + \frac{1}{\omega^2} \left(1 - u^2 - 2ue^{\frac{u}{\omega}} + 2u^2\gamma \left(e^{\frac{u}{\omega}} - e^{\frac{2u}{\omega}} - 2\gamma\right)\right)\right)} \quad (7.66)$$

Using the above results with the Cramer-Rao inequality (Equation 7.62) and the construction of possibility functions from statistical results (see Figure 5.4), fuzzy values for the parameters  $u$  and  $\omega$  ( $\mu_u$  and  $\mu_\omega$ ) can be obtained from the estimates. With the possibility functions  $\mu_u$  and  $\mu_\omega$ , definition of the fuzzy values of  $\theta$  and  $\beta$  can be obtained through the use of  $\alpha$ -level cuts and Equations 7.43 and 7.44. A transformation has to be made to make the equations isotonic however.

From Equation 7.43:

$$\text{let } \beta = 1/\omega \Rightarrow \mu_\beta(\omega) = \mu_\omega(1/\omega) \quad (7.67)$$

Substituted into Equation 7.44 then gives:

$$\theta = e^{u\beta} \quad (7.68)$$

which is isotonic because  $u$  and  $\beta$  are always positive in this application. The fuzzy



results can be substituted into Equations 7.26, 7.27 and 7.37 for use in the Poisson process model.

Thus the Regional Flood Estimation method is very versatile and enables data to be obtained where it is difficult otherwise with any pedigree. This enhances its success, but its pertinence only to the extent that the results are also helpful in achieving the required goals. The help in achieving goals is only appreciated by an analysis of the imprecision of the synthesized results in terms of what is helpful in any specific goal the information is being used for.

Fuzzy values for  $\mu_\theta$  and  $\mu_\beta$  obtained from actual data as developed above, and as mentioned above, can be used within the Poisson process model. The Poisson model is useful for calculation of summed expected flood-damage and for bank erosion if enough precision can be gained (see Section 7.6, Chapters 6 and 8).

Another type of information able to be obtained from the Regional Flood Estimation method is to determine the uncertainty (variance) of flood levels with an expected probability of exceedance given by  $1/T$ . This enables synthesis of fuzzy imprecise flood frequency curves. McKerchar and Pearson (1989) review such a formulation using  $n$  actual data to give an approximate measure of the uncertainty, in terms of variance:

$$V(Q_T) = (\omega^2/n)[(1.1128n-0.9066)-(0.4574n-1.1722)y_T + (0.8046n-0.1855)y_T^2]/(n-1) \quad (7.97)$$

where  $\omega$  is given by Equation 7.58 and  $y_T$  by Equation 7.21. The variance can be used to synthesize possibility functions of flood frequency curve values (see Figure 5.4). This enables imprecise flood frequency curves to be synthesised using equations 7.76, 7.77 and 7.60.

Part of the versatility of the Regional Estimation method is that if no actual data are available for a catchment it can be still used. However when using the Flood Estimation method without data from a catchment, the variance of both  $E(Q)$  and  $q_{100}$  have to be included, and as already mentioned, McKerchar and Pearson (1989) have established that the general values of them in Aotearoa / New Zealand are:

$$V[E(Q)] = (0.22E(Q))^2 \quad (7.70)$$

$$V(q_{100}) = (0.17q_{100})^2 \quad (7.71)$$

From analysis of variance of functions with two uncertain parameters McKerchar and Pearson (1989) give:

$$\begin{aligned} V(Q_{100}) &\approx q_{100}^2 V[E(Q)] + E(Q)^2 V(q_{100}) \\ &= q_{100}^2 [0.22E(Q)]^2 + E(Q)^2 (0.17q_{100})^2 \end{aligned}$$

$$= (0.28E(Q)q_{100})^2$$

$$\therefore V(Q_T) \approx x_T^2(0.22)^2 + (1-x_T)^2(0.28E(Q)q_{100})^2 \quad (7.72)$$

Using this result McKerchar and Pearson (1989) determined standard errors ranging from 19% for  $T=5$  years (i.e. a probability of exceedance of 0.2) to 30% for  $T=200$  years.

However if some actual data are available then greater certainty can be achieved.

McKerchar and Pearson (1989) define:

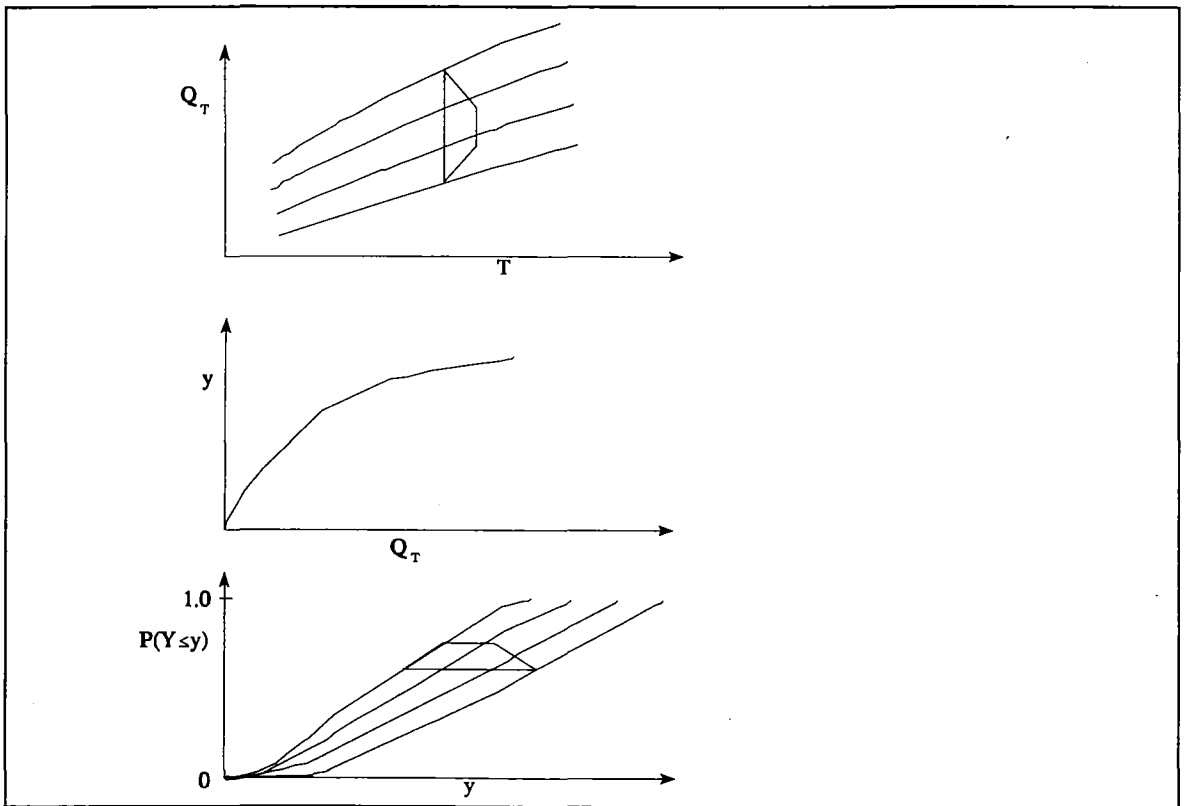
$$s = V(Q_{T_{site}})/[V(Q_{T_{site}}) + V(Q_{T_{map}})] \quad (7.73)$$

where  $V(Q_{T_{map}})$  is given by Equation 7.72 and  $V(Q_{T_{site}})$  by equation 7.69.

$$\text{and } V(Q_{T_{psd}}) = sV(Q_{T_{map}}) \quad (7.74)$$

$$\text{and } Q_{T_{psd}} = sQ_{T_{map}} + (1-s)Q_{T_{site}} \quad (7.75)$$

With these results imprecise flood frequency curves can be obtained. This is obtained by using a rating curve  $y = f_r(Q_T)$  mapping flow ( $Q_T$ ) onto stage  $y$ . Then the relationship  $P(Y \geq y) = 1/T$  enables flood frequency curves to be obtained. Figure 7.7 sketches the process if the rating curve is precise. In general the rating curve is not a precise however.



**Figure 7.7;** Synthesis of flood frequency curves.

When not precise it can be expressed through the use of generalised modus ponens involving mapping between two possibility functions. As a technique it is developed in Section 7.6 for application to bank erosion. Another possibility is to define a linguistic

truth weighting of the success of a precise mapping of flow onto stage. For example if the rating curve  $y=f_r(Q)$  is considered to be *quite true* then the values of  $\mu_y$  will be ITFMed accordingly after  $\mu_y$  is calculated using  $\alpha$ -level cuts, provided that the ordinary function of the rating curve is transformed to be isotonic (see Section 7.6.3).

## 7.6 MODELLING NON-ERGODIC PROCESSES

Thus practical hydrologic knowledge related to floodplain management can be obtained by explicitly incorporating objective uncertainty and imprecision into calculations. In doing so much of the criticism levelled at flood frequency analysis, reviewed above, has been corrected and the results integrated into methodology.

But what has yet to be integrated into methodology is the problem of long-term processes mentioned by Klemes (1989), and specifically focused on by Davies and Hall (1993) in terms of catastrophic floods. To an extent the issue is resolved because the problems with traditional flood frequency analysis assuming ergodicity and single governing distributions is their expression in distributions that are unrealistically precise. The explicit incorporation of uncertainty maintains realism to a greater degree. However specific time-dependent changes in the hydrologic systems need to also be taken into account so that long-term realism and hence accurate risk and economic analysis can be carried out. But if pertinence is considered then the design period determines the extent of change that needs to be considered. The rate of change may be such that they do not have to be considered. However some do! For example, the effect of deforestation, the possible effect of reforestation and other land use changes brought about rapidly by humans. Such punctuations of equilibriums need to be explicitly focused on, especially as they co-evolve with hydrology. To avoid self-fulfilling prophecies of doom, normative direction to hydrology is required. It forms part of the pertinence of hydrologic analyses. Analyses which allow for consideration of the change in streamflow and flood frequency given land use changes are very valuable. This can be included into models by adding fuzzy rules defining trends parameters may take given certain land use changes. The rules need to define if possible the sufficient conditions in order that the trend in the change of the parameter occurs, as well as the necessity that the land use changes to achieve the trend in parameter change.

The type of rule is dependent on the type of information. If the information is precise but uncertain, e.g. '0.3 of the catchment may be reforested', then approximate reasoning is appropriate. Sufficiency being given by:

$N(\text{land use change} \rightarrow \text{trend in parameter})$

Equation 5.27 can then be used to determine expected trends in parameters given different land use changes. Equation 5.27 can be interpreted as meaning that the greater the necessity of the trends, being due to the particular land use change, the less certain that the trends will be created by the land use changes. However it also means that if certain trends need to be achieved efficiently then the necessity of the particular land use change given by:

$$N(\text{trend in parameter} \rightarrow \text{land use change})$$

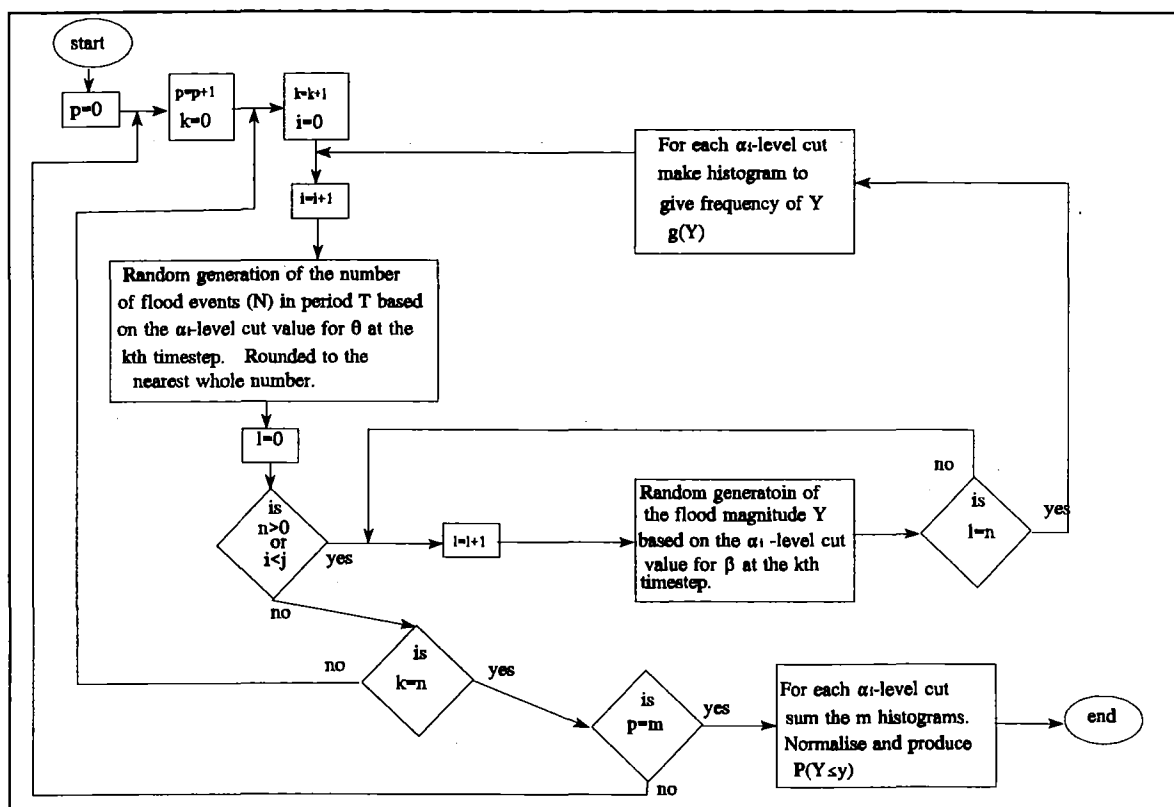
is helpful. The result is a possibility interval which can be used as defining a possibility function where the core equals the support.

If the information is imprecise as well as uncertain, for example ‘about 1/2 of the catchment may be reforested’, then generalised modus ponens/tollens has to be used (see Chapter 5). The effect of the necessity of having a particular land use change to bring about a parameter change on the achievement of the parameter change requires the use of generalised modus tollens, while the sufficiency that a parameter change will be brought about by a particular land use change requires generalised modus ponens. The scheme is given by:

a is A $\rightarrow$ b is B	the sufficient condition
a is A $\leftarrow$ b is B	the necessary condition
<u>a is A'</u>	
b is B <sub>1</sub> '	due to the sufficient condition
b is B <sub>2</sub> '	due to the necessary condition

However it is difficult to distinguish between sufficiency and necessity because of the condition required to infer generalised modus tollens that ‘if a is A then b is B’ is equivalent to ‘if b is not B then a is not A’(see Chapter 5). Therefore the distinction is not able to be made when information is imprecise as well as uncertain, and so questions of efficiency cannot be addressed.

Such vague trends, able to be implemented within pertinent periods through change in land use, enables the synthesis of possible flood frequency curves and associated parameters and to plan for creating the changes. However such information underlines the point Klemes (1989) made about the inadequacy of stationary stochastic statistical analyses. At best the change in parameter values that can occur over a period can be included as an imprecision and hence create greater imprecision in the result. But this is not helpful for the planning process unless a new ‘equilibrium’ of stationarity can be assumed at the end of the planned land use changes that give a new stationary process. To take into account the process of planned land use changes on parameters (Equation

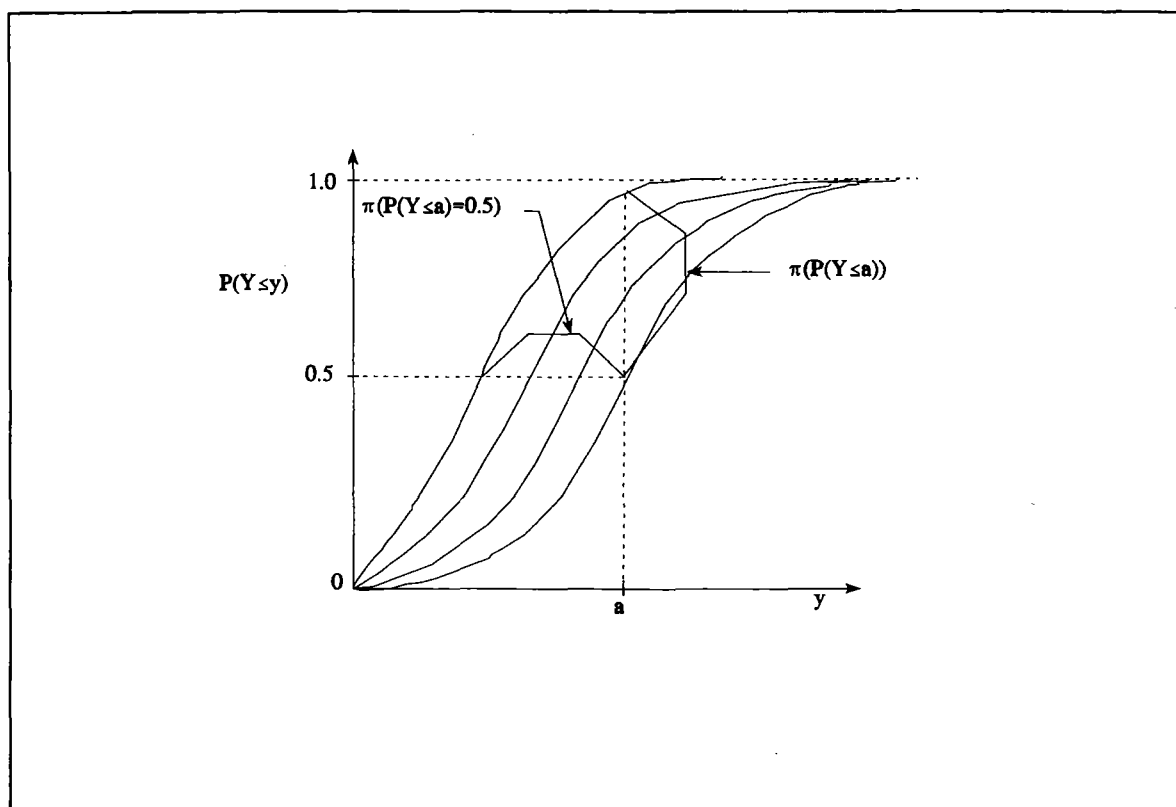


**Figure 7.8;** Simulation model for land-use changes.

7.26) involving summing changing values over a period requires the use of simulation modelling (see Figure 7.8). This would potentially produce a more precise result and thus allow more efficient and less adverse involvement by humans in our floodplain ecosystems, thus increasing the possibility of stable sustainable interaction.

The use of simulation modelling in this way can be called a scenario approach and is helpful in scoping possible alternatives as it adds extra technical information into the SSM process. It can also be considered the reconstructive stage after the deconstruction of hydrologic ‘prophecy’ and technical idealisation justifying coercion, as carried out above in determining the possible realistic use of stationary stochastic modelling.

Simulation modelling can use the rules for mathematical operations applied to fuzzy values thus making the calculus straightforward. The period concerned is discretised into specific times. For each of these the parameter values for the non-stationary random processes are calculated at required  $\alpha$ -level cuts. Monte-Carlo modelling is required to produce two random values at each time with the parameter values  $\theta$  and  $\beta$  as they stand at the particular time. The result is several sets of sequences of events, of varying length, and of varying values as a function also of the  $\alpha$ -level cut. Summing of the sequences for each  $\alpha$ -level cut will produce a fuzzy probability function output.



**Figure 7.9;** Fuzzy exceedance distribution.

## 7.7 EROSION

Erosion is one of the ways that the hydrologic system changes while simultaneously being a product of it, i.e. in co-evolution with the hydrologic system. Floodplain management requires that it be taken into account as a product of the hydrologic system because of local effects, especially on flood protection works. However the process is also part of an on-going process with long-term effects that can be gradual and catastrophic at different rates, and so methodology to analyze trends realistically is also required. The application to flood bank protection is addressed below.

### 7.7.1 Erosion of flood banks.

Rivers have a spatial characteristic which is much more difficult to model than is able to be given in 1-dimensional analysis. 2-dimensional models can model the spatial dimensions of river flow but are still conditional on fixed boundary conditions. In reality this assumption cannot be made uncritically. In effect this is what Klemes (1989) is arguing when he points out the importance of geomorphological trends. Hydraulic flow has momentum and hence force which can change the boundary conditions. Therefore the river system and its environment (boundary conditions) co-evolve. The result is the

complex process of stream meandering, including the very complex braided river networks.

The analysis of a river's co-evolution with its environment enters into the realm of pertinent analysis for floodplain management when the force in the streamflow causes bank erosion.

It is natural to consider bank erosion as related to the magnitude of a flood. It is also natural to consider the magnitude of a flood in relation to an erosion potential  $F_e(y, \ell)$ : defined to be both a function of the maximum (floodpeak) stage ( $y$ ) in a flood and the duration of a flood ( $\ell$ ) above a threshold stage. However it has to be remembered that over a design period, significant erosion may occur from more than one flood event. So erosion is also a function of the number of floods. Finally even though erosion is a continuous and non-uniform process, significant erosion (i.e. that for which it is pertinent to analyze) occurs at higher stage levels, i.e, when stopbanks are reached by flood waters, and so it is considered to consist of discrete events linked to flood events. Thus erosion may be modelled as a stochastic process of the occurrence of erosion events defined by  $F_e(y, \ell)$ .

However, because erosion is non-uniform, precisely because of complex streamflow patterns, the exact position of erosion cannot be determined. Thus 'erosion potential' is the best description when considering impact on floodbanks. The concept of 'erosion potential' assumes a uniform distribution of bank erosion along river banks which is given by the possible maximum at any place on the stretch of river. However the clarification of specific 'trouble spots' at any time needs to be recognised for the sake of efficient maintenance.

This is an example of the trends Klemes (1989) argues have yet to be taken into account in hydrology. Klemes is correct as determination of them will allow more efficient design. The calculation of averages is not useful for design for flood banks because erosion operates at specific sites at any point: maximum values have to be used. Floodbanks are required to survive the specific erosion and not an average erosive force over a stretch. Until more detailed analysis of erosion positioning is carried out, analysis (apart from intuitive decision rules about trends) has to very inefficiently assume a uniform distribution over pertinent river stretches, all with the same risk of a particular force which will only be occurring at specific sites in any given period.

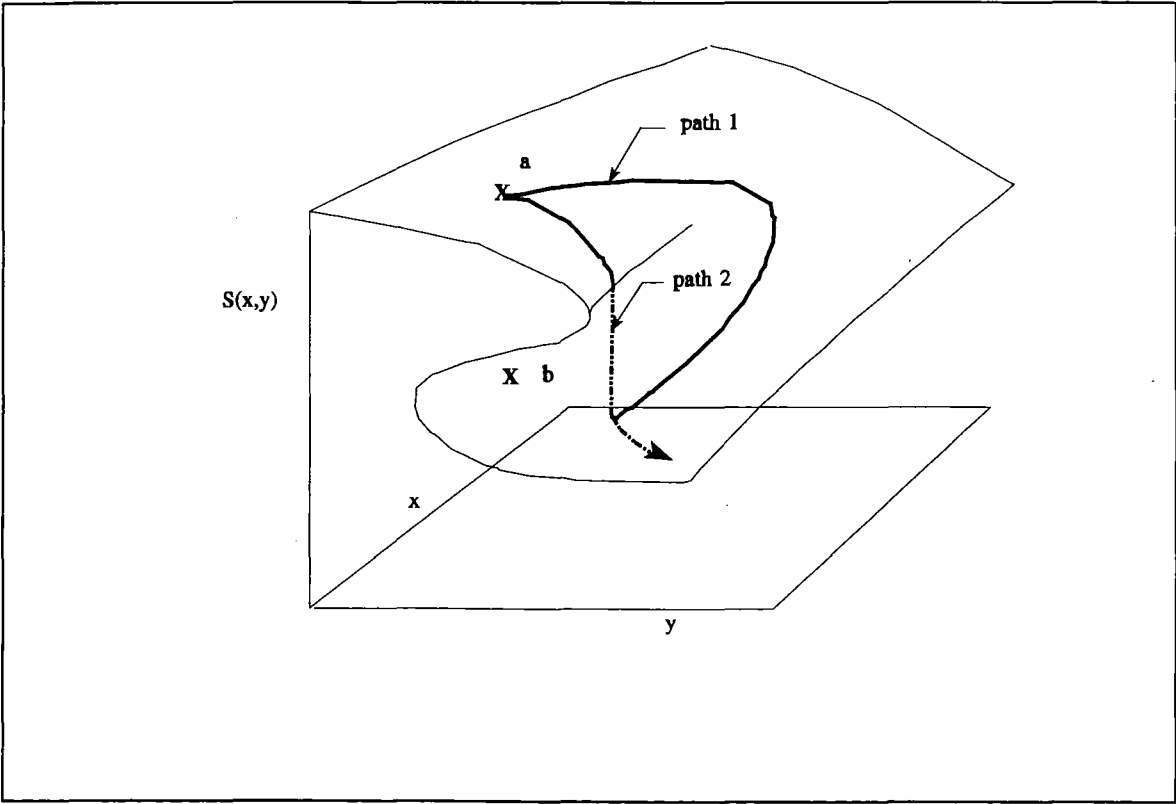
#### **7.7.1.1 Catastrophe theory.**

Trends found in the evolution of stream shape are known from observation and so fuzzy rules as to where expected trouble is and maintenance and strengthening is required

can be easily written. They are functions of time as well as of state parameters, e.g. roughness of floodbanks. At present it is done intuitively and included as a matter of course into floodplain management. However, sudden changes are less likely to be successfully obtained by such intuitive analysis. Catastrophe theory enables a theoretical basis to be given for the analysis of when (and where) expected changes are likely to occur. Catastrophe theory is based on thermodynamic analysis and uses the same criterion found empirically to apply for stream shape, namely that of lowest energy (highest entropy). The theory applies to where there are pertinent parameters that enable application of the rule of lowest energy. The model assumes that the system is always in equilibrium at the lowest energy state, but given that, unique expected state surfaces can be constructed.

It is worth noting here that the condition of equilibrium is recognised as not occurring in many situations, thus giving rise to non-equilibrium thermodynamics which is used as the basis for much contemporary research into system processes (e.g. Prigogine and Allen (1982), Jantsch (1982) and Prigogine and Stengers (1985)).

Catastrophe theory modelling of equilibrium situations that do occur is a topological problem as the surface has to be followed which can result in sudden changes



**Figure 7.10;** Catastrophe surface.



in state. The theoretical expectation of this is what models 'catastrophes' in natural systems. 'Catastrophe' here is purely an abstraction referring to sudden changes in state. So given a data base of observation of state as a function of significant parameters, prediction of sudden changes is possible, given that the continuous change in the significant parameters is known or predicted. The expected state surface for a system with two significant parameters is given in Figure 7.10 (after Graf 1988; Figure 2.20).

The two parameters  $x$  and  $y$  can produce gradually varying, or catastrophically changing paths in terms of the state  $S(x,y)$ . This is due to more than one equilibrium state existing for a specific  $x$  and  $y$  and is theoretically expected if there are more than one parameter. Graf (1988) has reviewed application of catastrophe theory to several hydrologic processes. As yet however application to position of bank erosion has not been attempted, but it is potentially a source of information to complement intuitive analysis of gradual trends. The fuzzy definition of significant parameters could allow uncertain yet informed decisions as to the expectation of a 'catastrophe'. The pertinence of the decision determines how the fuzzy result is interpreted, as developed in Section 7.4. above.

As well as trends (including sudden changes) in the positioning of erosive force, there is the effect of aggradation and degradation to be taken into account as they change the erosion potential in terms of the stage of the flood. They can be appreciated as a trend or as an imprecision depending on the period that is pertinent.

### 7.7.2 A stochastic model for floodbank erosion.

As well as the need to consider the long-term trends and sudden changes, long-term management of floodbank protection is also helped by an application of a stochastic model. The link of erosion event to flood event enables the stochastic model developed in Section 7.5 above to be used. Where the effect of pertinent catchment change in use needs to be considered in developing possible development scenarios, the simulation model in Figure 7.8 can be used.

The average expected erosion potential for a period  $T_e$  where stop banks are at a height  $z$  is able to be defined by:

$$E(\xi_z) = \theta \int_0^z \int_0^\infty P(Y \cap \ell) \cdot F_e(y, \ell) d\ell dy \quad (7.76)$$

where  $\theta$  is the mean rate of occurrence of flood events and  $\xi$  is the total erosion potential given by the sum of  $F_e(y, \ell)$  in the period  $T_e$ . However as mentioned above this result is

not useful (pertinent) for floodplain management. What is required is a probability function of the expectation of actual erosion events. How to calculate  $F_e(y, \ell)$  is addressed in Section 7.7.3.

The probability of occurrence of total erosion potential for a period  $T_e$  can be described by an equation in the form of Equation 7.77 below:

$$P(\xi_e \leq \xi_z) = P(N=0) + \sum_{k=1}^r P(\xi_e \leq \xi_z | N=k) \cdot P(N=k) \quad (7.77)$$

where  $r$  is a reasonable estimate for the maximum number of floods expected in the design period  $T_e$ . A reasonable figure can be given by:

$$r = T_e / (\theta + 3\sigma_\theta) \quad (7.78)$$

as this approximately contains 99.5% of expected possible sequences of events. But the determination of  $\xi_z$  involves the two parameters of stage  $y$  and duration  $\ell$  of flood which occur as random variables given by probability functions  $P(y)$  and  $P(\ell)$  and are not independent. Therefore for an individual erosion event, i.e. when  $k=1$ ,  $\xi_e = F_e(y, \ell)$ :

$$P[F_e(x, \ell) \leq \xi_z] = \int_0^{\ell_1} \int_0^{y_1} P[y \cap \ell | F_e(x, \ell) \leq \xi_z] dy d\ell \quad (7.79)$$

$$\begin{aligned} \text{where } P[y \cap \ell | F_e(y, \ell) \leq \xi_z] &= P(\ell | y)P(y), \text{ if } F_e(y, \ell) \leq \xi_z \\ &= 0 \quad \text{otherwise} \end{aligned} \quad (7.80)$$

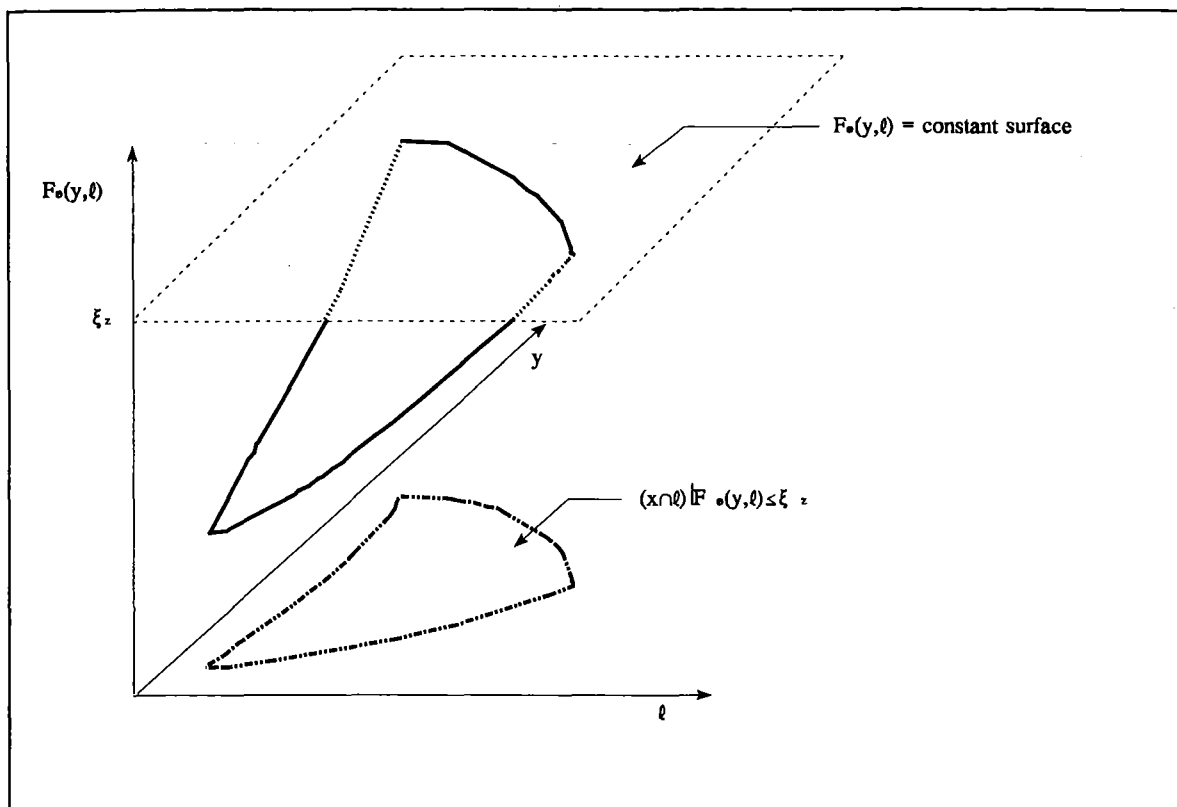
where  $y_1$  is the height of the stopbank and  $\ell_1$  is a reasonable maximum duration of a flood obtained from data and where:

$$P(y) = \beta e^{-\beta y}$$

A fuzzy estimate of  $\beta$  can be obtained from the methods developed in Section 7.4.

$P(\ell | y)$  requires synthesis from data. Streamflow data requires sampling at different levels of stage ( $y$ ) to produce  $P(\ell | y=Y)$ . The resulting set of probability distributions require to be aggregated together to give a general fuzzy result. The possible events resulting from the sampling process give the core for the possibility function. Short of a statistical tool to estimate variance due to the sampling, subjective definition of the foot of the possibility function is required. Estimates of the shortest and longest durations  $\ell$  for a given peak  $x$  can be used to define a  $\pi(\ell | x)$ . It is necessary to relate  $y$  to  $\ell$ :  $F_e(y, \ell) = \text{constant}$ . A graphical representation of  $[x \cap \ell] | [F_e(y, \ell) \leq \xi_z]$  is given in Figure 7.10.

For  $k > 1$  it is necessary to consider the summation of several random distributions. As  $P(F_e(y, \ell))$  is not an exponential distribution the use of a Gamma distribution as in



**Figure 7.11;** Erosion potential surface.

Equation 7.8 is not possible. So let  $F_e(y, l) = x$  and  $\xi_e = X$  and consider  $k$  independent events of which the sum is  $X$ :

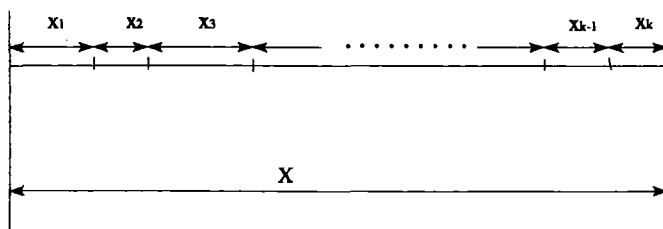
$$x_1 + x_2 + x_3 + \dots + x_k = X$$

Also let the probability distribution that each event comes from be identical and so the probabilities for each event are given by:

$$f(x_1), f(x_2), f(x_3), \dots, f(x_k)$$

The Central Limit theorem states that the distribution of the sum of any  $n$  identical random distributions, as  $n \rightarrow \infty$ , tends to a normal distribution. The applicability of the central limit theorem is dependent on the shape of the distribution and the number of them added together. Hines and Montgomery (1980) give guidelines that if  $f(x)$  is no less normal than a uniform distribution then the Central Limit theorem applies for values  $n > 12$ . It cannot be assumed that  $n$  is always, or usually, greater than 12 and so the central limit theorem cannot be used to determine the expected distribution of the sum of individual distributions.

Consider the possibilities for  $\sum x_i = X$ . It is neither a case of the possible



**Figure 7.12;** Segmentation of a period.

permutations nor that of the possible combinations. Consider a series of  $k$  events (see Figure 7.12).

$x_1$  can be in the range  $[0, X]$

$x_2$  can be in the range  $[0, X - x_1]$

$x_3$  can be in the range  $[0, X - x_1 - x_2]$

$\vdots$   $\vdots$

So for example when  $k=4$ :

$$P(X) = \int_0^X f(x_1) \int_0^{X-x_1} f(x_2) \int_0^{X-x_1-x_2} f(x_3) \cdot f(x_4 = X - x_1 - x_2 - x_3) dx_3 dx_2 dx_1$$

Now if  $f(x)$  is an exponential distribution for example:

$$f(x) = \beta e^{-\beta x}$$

then a gamma distribution is expected where  $k=4$ , i.e:

$$\begin{aligned}
P(X|N=4) &= \int_0^X \beta e^{-\beta x_1} \int_0^{X-x_1} \beta e^{-\beta x_2} \int_0^{X-x_1-x_2} \beta e^{-\beta x_3} \beta e^{\beta(-X+x_3+x_2+x_1)} dx_3 dx_2 dx_1 \\
&= \int_0^X \beta e^{-\beta x_1} \int_0^{X-x_1} \beta e^{-\beta x_2} \beta^2 (X-x_1-x_2) e^{\beta(-X+x_2+x_1)} dx_2 dx_1 \\
&= \int_0^X \beta^4 e^{-\beta x} \left( \frac{x^2}{2} - x x_1 + \frac{x_1^2}{2} \right) dx_1 \\
&= \frac{\beta^4 X^3 e^{-X\beta}}{6} \quad \text{as expected}
\end{aligned}$$

Generally the solution is:

$$P(X|N=k) = \int_0^X f(x_1) \int_0^{X-x_1} f(x_2) \dots \int_0^{X-x_1-x_2-\dots-x_{k-2}} f(x_{k-1}) f(x_k) dx_{k-1} \dots dx_1 \quad (7.81)$$

where  $x_k = X - x_1 - x_2 - \dots - x_{k-1}$

Equation 7.81 can be solved numerically to obtain a 2-dimensional array and used to also solve numerically:

$$\begin{aligned}
P(X \leq x | N=k) &= \int_0^x f(X|N=k) dX \\
&= P(\xi_e \leq \xi_z | N=k) \quad (7.82)
\end{aligned}$$

A computer programme to do so is included in Appendix A.3. This can be considerably simplified when the Central Limit theorem is applicable. Equation 7.77 can be solved in two parts. Equation 7.81 can be used for when  $k \leq 12$ , and for when  $k > 12$  the distribution function of the normal distribution is used (Montgomery and Hines 1980):

$$P(X \leq x) = \int_0^x \frac{e^{-\frac{1}{2} \left( \frac{u-\mu}{\sigma} \right)^2}}{\sigma \sqrt{2\pi}} du$$

where  $\sigma^2$  and  $\mu$  are the variance and the mean respectively. This needs to be solved numerically, including in general  $\sigma$  and  $\mu$ , but as computerised analysis is involved, the use of the tabulated solution of the transformation  $z=(d-\mu)/\sigma$  which is readily available gives:

$$\Phi(z) = \int_0^z \frac{e^{-\frac{u^2}{2}}}{\sqrt{2\pi}} du$$

It is required to solve for  $f(x)$ :  $x \in ]0, \xi_e]$  in terms of  $y$  and  $\ell$  thus:

$$f(x) = \int_0^{\ell_1} \int_0^{y_1} P(\ell|y) P(y) dy d\ell \quad (7.83)$$

where  $F_e(y, \ell) = x$ , using the empirically or otherwise derived relationship between  $y$  and  $\ell$  mentioned above (see also Section 7.7.3.2).

Substituting the results from Equation 7.84 into equations 7.81-83 enables Equation 7.77 to be solved generally. The model given by Equation 7.77 assumes however that the length of the stretch of river has no bearing on the problem. In fact this result is the limiting case as the length approaches infinity. It assumes that if floods occur, then erosion events will also occur in the stretch of river of interest. Given flood events may in fact only cause erosion outside the stretch of interest. So a further probability of occurrence of  $N$  erosion events within a length of stretch of river is required, and which Equation 7.77 is conditional upon. The occurrence of  $N$  events is a spatial problem as well as a time series problem. However because the assumption held to give Equation 7.77 is conservative, it does not produce a false result, but only an inefficient result.

Due to parametric imprecision in  $\beta$  and  $F_e(y, \ell)$ , calculation of  $P(\xi_e \leq \xi_z)$  from Equation 7.77 will be fuzzy, but able to be solved through the use of  $\alpha$ -level cuts. It is isotonic.

#### 7.7.2.1 Risk from bank erosion.

The analysis of risk requires a PMRM where definition of the appropriate partition between low probability high magnitude and other events is made. However, unlike what is usually carried out in PMRM, the definition of the risk comes first so as to define the partition rather than vice-versa. Also because the event of failure due to bank erosion is a single catastrophe (i.e Boolean), calculation of expected technical risk (see Section 6.2.1) is not appropriate. All catastrophes that may occur above the partition are equally failures. Therefore what is of interest is the probability itself without any need for quantification of the magnitude of effect to be made.

Floodbanks can be designed to resist a certain erosion potential  $\xi_d$ , thus giving a risk of failure:

$$P(\xi_e > \xi_d) = 1 - P(\xi_e \leq \xi_d) \quad (7.84)$$

and so its solution is a trivial extension of the solution of Equation 7.77.

The risk  $P(\xi_e > \xi_d)$ , is a function of the design variables  $T_e$  and  $\xi_d$  given the hydrological data. Therefore there are two main approaches that can be made. Either  $T_e$  is made

short enough by developing an on-going maintenance program so that erosion can not add up to be greater than  $\xi_d$ , or stopbanks are made to a capacity with a large  $\xi_d$  to resist erosion over a longer period. With these two parameters a design level of risk can be determined. The two parameters are chosen within a broader set of criteria in management. Cost and functional operation of staff also need to be taken into account. Another possibility is that the hydrologic system can be attempted to be changed thus changing  $\xi_e$ . If this is considered then analysis of what catchment changes bring parameter changes needs to be considered. If  $T_e$  is a long period then a simulation method to solve for  $\xi_e$  is required. This is not likely to be the case however as continuing maintenance is cost-effective unless there are other reasons for changes in land use as well.

The decision as to what is an appropriate risk given by  $P(\xi_e > \xi_d)$  is a value judgement socially determined. Once a value has been decided upon, decisions about levels so as to resist the expected erosion potential can be determined through the use of the above equations.

As  $T_e$  gets smaller the result becomes more dependent on the length of stretch of river, but if the erosion is up to floodbanks then it can be expected to be near-uniform along the bank. However zoning of stretches of river that are erosion prone, in any period, is required of floodplain management, and is necessarily still carried out intuitively. But the judgements when defined as possibility functions are of high pedigree. Also necessary are judgements about trends occurring with aggradation and degradation. Even some wariness as to expected sudden changes may be gained intuitively. Some discussion as to the features of states before sudden changes in alluvial fans is given by Straight (1992).

Together with fuzzy rules about the pertinent stretches of river needing protection and levels of protection (in terms of resistance to erosion potential), management strategies can be determined.

The information required for design that relates design parameters to erosion potential to be resisted, is necessarily gained from relating river stage to river flow and hence to erosive force and erosion potential. Similarly the ability of flood protection to resist erosive potential also needs to be defined.

However the standard flood protection techniques of planting trees and the use of groynes also alter the relationship. Therefore the fuzzy effect of the protection techniques on the erosion potential have to be intuitively defined. This is best included in the definition of the ability of flood protection to resist the erosive force as a modification of

the design erosion-resistance-strength because erosive potential from floods remains defined only by the parameters of stage and duration of flood, thus allowing the use of the equations based on a stochastic model.

But because there is differential cost involved in the protection measures, decisions as to what is the appropriate design for bank erosion has to be integrated within overall management criteria. The process is likely to be iterative and is discussed further in Chapter 8.

The determination of possibility functions describing the various features in terms of their affect on erosive potential, and trends defining what are pertinent stretches to be concerned about, involve subjective judgement by experts. Assuming that the expert judgements are coherent, in the sense of supporting each other, aggregation of the fuzzy expert judgements for use in analysis can be carried out. Equation 7.85 is a generalisation of a form given by Dubois and Prade (1988):

$$\forall s \in S, \quad \pi_n(s) = \frac{\pi_1(s) \wedge \pi_2(s) \wedge \dots \wedge \pi_n(s)}{\sup_{s \in S} \pi_1(s) \wedge \pi_2(s) \wedge \dots \wedge \pi_n(s)} \quad (7.85)$$

If  $\wedge$  is the min operator as it is in Godel's MVL (see Chapter 5) then the aggregation process is being modelled as gaining pedigree as un-needed vagueness is discarded. Modelling of other types of expert information is possible. It is reviewed in Chapter 8.

As a general principle the defining of possibility functions for expert judgement allows the inclusion of all experts and so widens the information source as well as encouraging wider participation in the management process.

### 7.7.3 Determination of erosion potential.

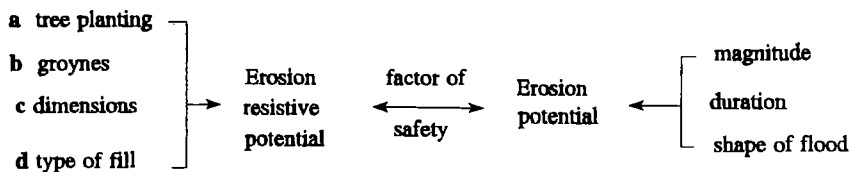
There are two aspects of erosion that need to be taken into account: the determination of erosion resistive potential and erosive potential. They are both fuzzy and may be given by:  $\pi(\xi_B)$  and  $\pi(\xi_z)$  respectively. The overall interaction is sketched in Figure 7.13.

#### 7.7.3.1 Erosion resistive potential.

Firstly it is necessary to determine independent parameters. The independence has to be in terms of the effect they have on erosion resistance. To develop a physically based model the development of parameters is in terms of potential resistive force to scouring. It is assumed that erosion is a function of time and the rate of scouring.

The resistive force is what is the value of the parameter in this context. The





**Figure 7.13;** Erosion processes.

dimensions of flood protection structures and type of fill are independent over the range of dimensions being considered. However tree planting and the use of groynes are not. Tree planting and the use of groynes need to be aggregated to form a compound parameter. The compound parameter is given by the value of tree planting or the value in the use of groynes or the use of tree planting and the use of groynes. The third possibility involves tree planting and the use of groynes, and is itself a set of possibilities. The third possibility decomposes into: the use of groynes given the use of tree planting and the use of tree planting given that groynes are in use, i.e. the sum of the effect of groynes and tree planting given that each event effects each other. Consequently the compound factor is given quantitative form by the use of addition between the two conditional terms in the decomposition. Using the letter signs in Figure 7.13, rules to determine the overall potential erosion resistive force can be defined by:

$$\xi_B = c \cdot d \cdot e \quad (7.86)$$

where:

$$e = a \text{ or } b \text{ or } a \text{ and } b \quad (7.87)$$

where:

$$\mathbf{a} \text{ and } \mathbf{b} = \mathbf{a} \mid \mathbf{b} + \mathbf{b} \mid \mathbf{a} \quad (7.88)$$

All values;  $\mathbf{a}, \mathbf{b}, \mathbf{c}, \mathbf{d}$ , and  $\mathbf{e}$  are fuzzy. The multiplication used in Equation 7.87 produces an isotonic function and so calculation of  $\mu_{\xi_b}$  is straightforward. The logical term 'or' in fuzzy calculus is conjunction and is usually given by the max operator:

$$\forall s, \mu_{\xi_b}(s) = \max(\mu_a(s), \mu_b(s), \mu_c(s)) \quad (7.89)$$

Other forms for conjunction are possible and the issue is discussed in Chapter 9.

Addition is isotonic and so calculation of  $\mu_{\mathbf{a} \text{ and } \mathbf{b}}$  is straightforward.

The ability of the type of fill to resist erosion is fuzzy but able to be given some form through the use of geomechanics theory. Some particular fill's resistance to scouring can be used as the basic unit for the overall analysis. Absolute values for any of the parameters of  $\xi_b$  in the sense of being relative to general physical theory are not required. The analysis here has only to allow comparison of erosive force from a river and the ability of the bank to resist it. Erosive force of the river is able to be defined in terms of this basic unit. It could be labelled anything. Let us say 'fill strength'.

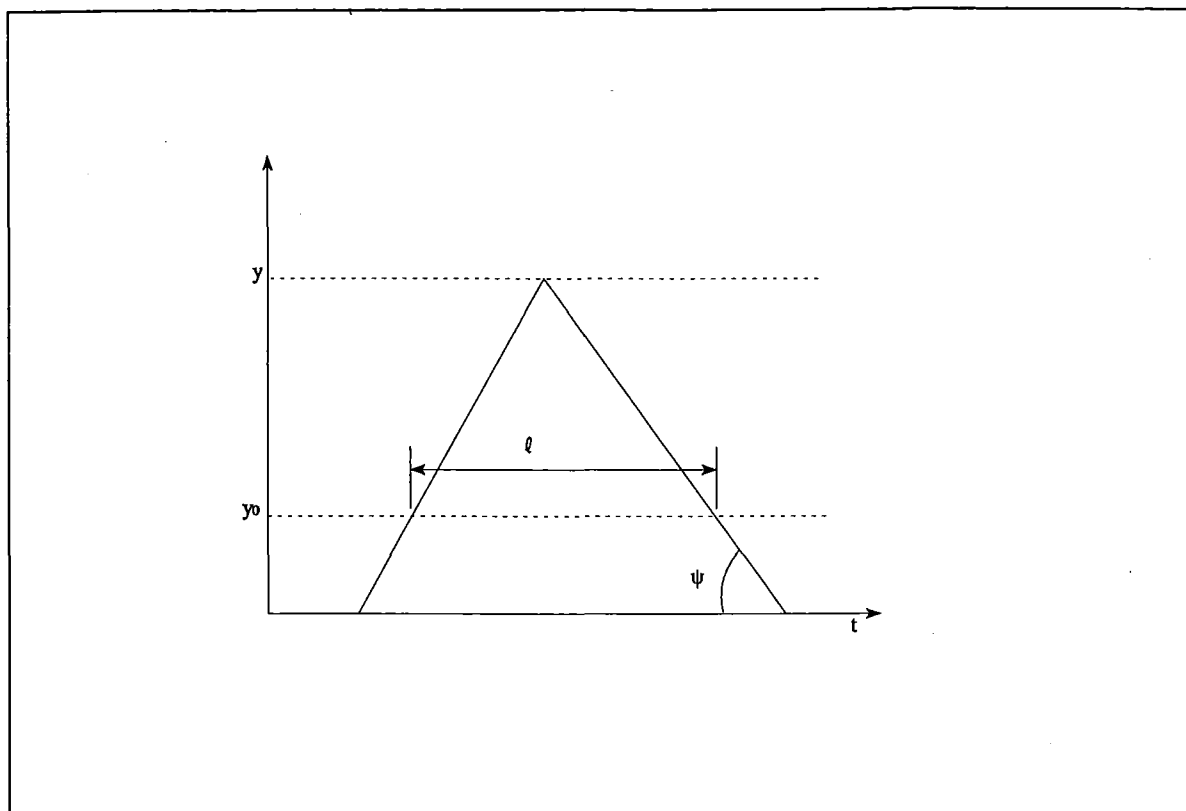
The value of the dimensions of the structure are also fuzzy yet able to be given straightforward form through the use of analysis of shear force, as part of geomechanics theory. It can be given as a factor to apply to the basic unit given by the type of fill.

The compound term is also applied as a factor to the basic term and can be synthesised through the use of the rule outlined above. Determining values to act as factors is necessarily based on both judgement and empirical evidence; both of which are fuzzy.

#### 7.7.3.2.1 Erosive potential.

Erosion potential due to river flow can also be linked to erosive force. The force is given by hydraulic analysis in terms of change in momentum that occurs, and so is related to the angle of attack of the river. Because the only hydrologic parameters involved in the stochastic analysis of erosive force are stage and duration of flood, the effect of the angle of attack of the river has to be included in the fuzziness of the description.

The relationship between stage and duration of flood creates fuzziness because the total erosion potential is given by the integration of the effect of a flood defined by the two parameters of stage referring to the peak stage, and duration referring to the duration of the flood above some threshold. The duration of flood refers to the period of scouring, and the flood peak to the rate of scouring. The threshold is appropriately given by the



**Figure 7.14;** Flood hydrograph.

base of the flood protection structures. A triangular model can be made for the shape of a flood thus giving the relationship between  $\ell$  and  $y$  (see Figure 7.14). Let  $m=\tan\psi$ .

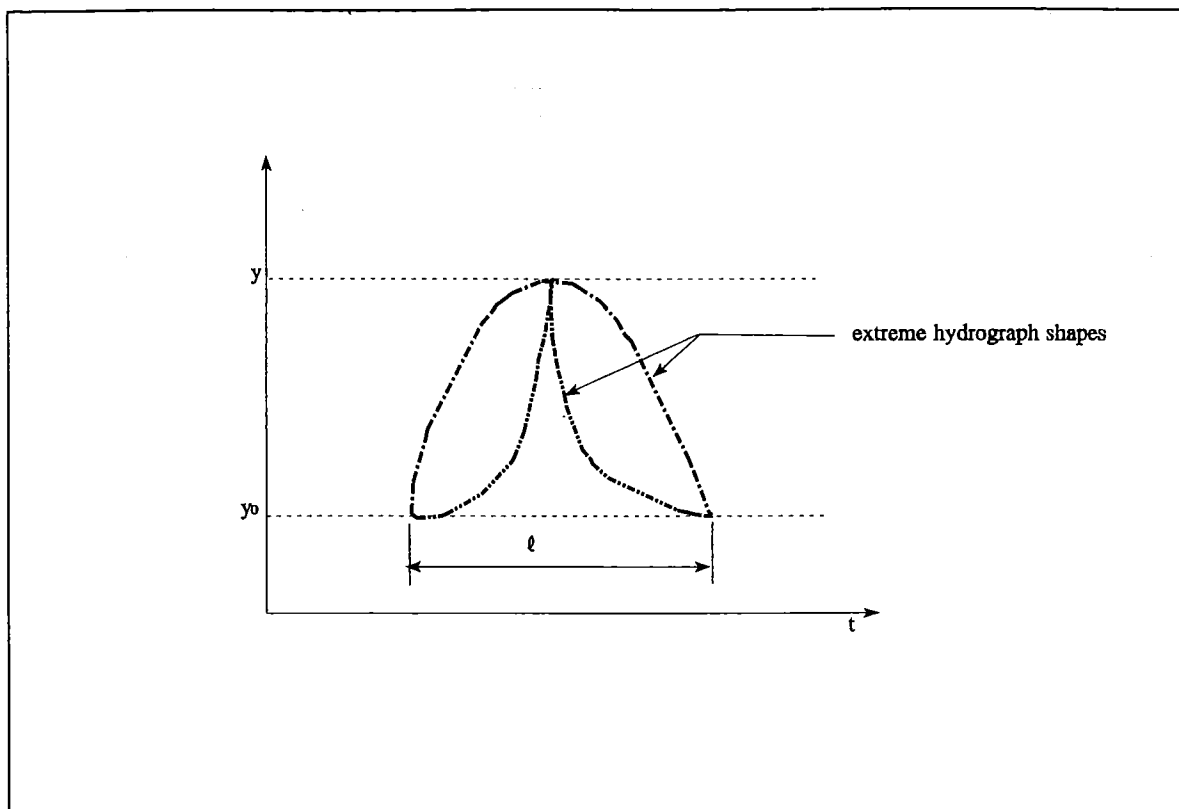
Erosion potential for each event is given by:

$$F_e(y, \ell) = \int_0^{\ell} f_e \circ g(t) dt \quad (7.90)$$

where  $g(t)$  defines the shape of the flood event and  $f_e(y)$  is the erosive force causing the rate of scouring. For the triangular form for  $g(t)$  given above, Equation 7.90 becomes:

$$F_e(y, \ell) = \int_0^{\frac{y-y_0}{m}} f_e(y_0 + mt) dt + \int_0^{\ell - \frac{y-y_0}{m}} f_e(y_0 - \frac{y-y_0}{\ell - \frac{y-y_0}{m}} t) dt \quad (7.91)$$

$F_e(y, \ell)$  is fuzzy because the shapes are only an idealisation. Determining what the fuzziness is requires considering the different shapes of floods that are possible. Extreme shapes need to be considered so as to form the support and core of  $\pi(F_e(y, \ell))$ . See Figure 7.15 for suggested extreme shapes. Exponential functions are useful, as they are easily integrated. Alternatively numerical integration is always possible if actual flood events are used as characteristic extreme forms. As mentioned above, erosive force  $f_e(y)$  is able



**Figure 7.15;** Extreme shapes of flood hydrograph.

to be defined in terms of defined erosive resistive force with 'fill strength' as the basic unit.

The probabilities associated with  $F_e(y, \ell)$  so as to allow determination of  $\xi_z$  and  $P(\xi_e \leq \xi_z)$  are fuzzy.  $P(N)$  as given by Equation 7.26 is imprecise.  $P(\ell|x)$  is also and has to be gained from sampling streamflow data as also mentioned above. However as already mentioned Equation 7.77 is isotonic which makes calculation using  $\alpha$ -level cuts straightforward.

#### 7.7.3.2.2 Erosive force.

The analysis above is a physically-based model that allows in principle the calculated erosive force and resistive force to be equated by application of Newton's laws. An objective reality is appealed to by both definitions, thus allowing them to be equated. In general the relationship between concepts cannot be gained by appealing to an objective reality in such a way that allows their definition independent of each other. Ultimately all scientific objectivity is relative to some defined physical system of limited scope. The dream of a 'grand unified theory' for science still eludes scientists even though it has been the inspiration of 'hope' of scientists for several centuries now (Jones, R S 1982). Even a

physically-based model is of limited scope when there is not sufficient evidence to define each concept adequately. Theoretically it is possible with the study of erosive force but in practice because of lack of data a direct relationship between the concepts of erosion resistive force and erosive force is suggested.

Empirical data about an event (several to seek corroboration) enables a fuzzy relationship to be obtained thus enabling calibration. To keep the model 'physically-based' involves defining one or other of the two equal and opposite forces as the unit force. Generalised modus ponens is a method that can be used to carry out the process.

From a particular empirical relationship between an observed vague erosion resistive force (in terms of the defined vague parameters) and vague erosive force (also in terms of vague defining parameters) a relationship between them can be determined by the fuzzy statement:

$$X \text{ is } f_e(y) \rightarrow Y \text{ is } f_b \quad (7.92)$$

$f_b$  is  $\xi_b$  for a unit period and so defines a rate of scouring. The relationship is assumed to be causal because of the underlying physical mechanism being modelled. "X is  $f_e(y)$ " and "Y is  $f_b$ " are possibility functions,  $\mu_e$  and  $\mu_b$ . The relationship between the two is obtained empirically and defines a MVL. A standard type of MVL can be sought to model the one empirically implied, or alternatively the one implied used in further calculations for the particular case.

Generalized modus ponens is required to obtain a fuzzy description of implied erosion resistance (X is  $f_b$ ) given a calculated fuzzy erosive potential (Y is  $f_e$ ) when the calculated erosive potential is different to the one in the calibration:

$$\frac{X \text{ is } f_e(y')}{X \text{ is } f_e(y) \rightarrow Y \text{ is } f_b} \quad Y \text{ is } f_b \quad (7.93)$$

The resulting fuzzy "Y is  $f_e$ ," is then able to be interpreted as the 'real' erosive potential according to the physical model. Generalised modus ponens becomes increasingly vague the further  $f_e(y)$  is from  $f_e(y)$  used for the calibration. For practical application a relationship between  $f_e(y')$  and y needs to be obtained. This enables  $f_e'(y'')$  to remain close to  $f_e(y)$  by transforming  $y' \rightarrow y''$ . The transformation required has similarly to be applied to the values of "Y is  $f_b$ ". As a first and physically reasonable approximation  $f_e(y)$  can be defined as a function of water velocity because force is given by the change in momentum which is related to water velocity. Further velocity is a function of streamflow. Thus a rating curve relationship is recognised. Once again, absolute values

are not required; only the relationship between  $Q$  and  $y$ . So functions for the rating curve are required. These can be derived from the use of St Venant equations in river routing modelling or synthesized empirically. They will be site-specific. Using the rules for arithmetic operations on fuzzy values enables the transformation to be made. The relationship:

$$Q=k(y-a)b$$

is often assumed (Linsley et al. 1982). Standard methods to estimate  $k, a$  and  $b$  exist. Thus assuming that  $f_e(y) \propto Q$  enables a ratio between  $y''$  and  $y$  to be obtained through consideration of a ratio between  $f_e(y)$  and  $f_e(y)$ , i.e:

$$y''/y = k_e = [f_e(y')/f_e(y)(y-a) + a]/y \quad (7.94)$$

where  $y'$  and  $y$  are given by the mid-point of their respective cores as fuzzy values.

Using this relationship "X is  $f_e(y')$ " can be transformed to "X is  $f_{e''}(y'')$ " thus:

$$\text{let } y'' = k_e y' \Rightarrow \mu_{f_{e''}}(y'') = \mu_{f_e}(y'/k) \quad (7.95)$$

Therefore the modus ponens inference is transformed to:

$$\frac{\begin{array}{l} \text{"X is } f_{e''}(y'')\text{"} \\ \text{"X is } f_e(y)\text{"} \rightarrow \text{"Y is } f_b\text{"} \\ \text{"Y is } f_{b''}\text{"} \end{array}}{\quad} \quad (7.96)$$

To complete the process, "Y is  $f_{b''}$ " has to be transformed to "Y is  $f_b$ ". This is done thus:

$$\mu_{f_b}(v) = \mu_{f_{b''}}(k_e v) \quad (7.97)$$

The erosion potential of a certain-sized flood is defined by the resulting erosion resistive potential that is inferred, i.e.  $f_b$  is used to define  $F_e(y, \ell)$ . The first step to do this is to empirically make  $f_b$  a function of  $y$ , i.e.  $f_b(y)$  is substituted for  $f_e(y)$ . Then  $f_b(y)$  is substituted for  $f_e(y)$  in Equations 7.90 and 7.91. This allows design to proceed straightforwardly through comparison between design erosion resistive force given by Equation 7.86 and that deduced from equations 7.94-97.

### 7.7.3.3 Application in a stochastic model.

Once erosion potentials have been calculated so they coherently coexist in terms of a physically-based model as given above, the inequalities used in Equations 7.77 and 7.79 can be calculated and are what are used for design purposes. For example  $\xi_d > \xi_z$ .  $\xi_d$  is given by a possibility function derived from fuzzy parameters related to flood protection structures (Equation 7.86). Equation 7.77 determines the erosion potential that is expected to be produced stochastically. The comparison between the fuzzy values involves the use of Equations 5.18-21.

The use of the inequalities here have to be made straightforward in the spirit of the concept of factors-of-safety. Therefore it is appropriate to be risk-averse so that even with the imprecision there is no risk associated with the calculus of the inequality. Therefore the strict exceedance necessity measure given by:

$$N(\xi_d > \xi_z) = 1 - \sup \min(\mu_{\xi_d}(u), \mu_{\xi_z}(v)) \quad (7.98)$$

is appropriate. However linguistic interpretation of safety through using the linguistic interpretation of the various inequalities outlined in Chapter 5 (Section 5.6.1.7) is possible.

What is effectively done is that the lower the pedigree of analysis is (the greater the imprecision expressed in "X is  $f_a(y) \rightarrow Y$  is  $f_b$ ") the greater the 'factor of safety' that has to be applied, and hence the less efficient the design can be.

## 7.8 CONCLUSION

With the calculation of realistic description of parameters for hydrological models outlined above, technical hydrology can be integrated into decision-making without being coercively ideological.

At worst the information produced will indicate what real information does exist and where the hydrologist has got technical knowledge to offer. This clarifies where dialogue to define social goals is required and so helps overcome the temptation of professional elitism prophecy so as to gain social privilege.

At best it enables realistic consideration of the technical hydrological consequences of alternative social goals and methods to achieve social goals, and so helps evaluate feasible and efficient designs as well as coherent social goals.

# Economic Analysis

Economics is commonly defined as a social science (Collins Shorter English Dictionary 1993). So to enter into an analysis of economic theory it is perhaps appropriate to consider it in the context of the social science principles developed in Chapter 4. There a social constructivist theory exploring reflexive system dynamics involving the interaction of creative individuals within the contexts of social structure, ecology and spirituality was outlined. The theory outlined a co-evolution of human culture with its environment whilst and through nurturing the ontological growth of the individuals/world involved.

Therefore to make economic decisions which are of interest in floodplain management is to consider system analyses aimed at giving policy advice within the context of co-evolution. Thus economic methodology to be adequate in informing floodplain management, has to be reflexively carried out so as to allow creative decisions involving deconstruction and reconstruction as an expression of the ethically inspired creativity of individuals within the process.

## 8.1 INTRODUCTION

In economic theory a distinction is often made between descriptive and normative theory, in keeping with the distinction made by Hume between facts and values at the core of 'Enlightenment' culture (Schwartz 1986). It is helpful to consider the process of making economic decisions as carried out in floodplain management in terms of this distinction, as well as the social theory developed in Chapter 4.

As developed in Chapter 4, descriptive social science acts as self-fulfilling prophecies, and hence acts normatively, because it forms a worldview with resulting structural power relations implicit in it. This is not a problem as long it is reflexively recognised, as it is what reconstruction entails. It only becomes a problem when individuals within the process do not see the normative aspect and so are not empowered to express their own creative moral freedom with reflexivity and cooperation. They conclude fatalistically instead that the language game of existing structural power relations and worldview are unchangeable and absolute. This ignorance is promoted when the Is-Ought fallacy is made and the social science descriptions are explicitly used as the basis



for normative theory (see Chapter 3). This is distinct from making the 'naturalistic fallacy' which is inherent in all normative theories (see Chapter 3).

What is required is that the making of the 'naturalistic fallacy' be carried out in such a way that allows for the creative reconstruction of theory through reflexive thought by those involved. It is the essentializing which makes theory absolute which has to be avoided. Then the Is-Ought fallacy is also avoided (see Chapters 3 and 4).

What this means in the process of making decisions, is to make both critical descriptions (deconstruction) of what is, so as to point out what has to change, (even if it was appropriate at one stage in the co-evolution) and descriptions of what it could be so as to make it better (a reconstruction of theory). In doing so, the role of social theory to act as a self-fulfilling prophecy is explicitly carried out and achieves both normative and descriptive aims. The social system that comes into being in the future is inherently socially constructed through theorising carried out at present.

Another feature of the co-evolutionary system involving reflexive decision-making is that critical social theorists constructing descriptions of what the system 'is' (i.e. what the system should not be but is) have a responsibility to also nurture reflexive creative freedom and dialogue between all within the moral community. To fulfil the meta-ideals developed in Chapter 3 requires that social goals be determined by participation by all.

Making decisions within the co-evolving process involves defining ideals and goals that the reconstructions are trying to achieve. The ideals and goals need to be based within a coherent worldview that understands both the constraints and the ideals being sought - once again the synthesis of descriptive and normative aspects (see Chapter 4). The reflexive process by participants requires them to perceive the potential which the system can co-evolve into. Seeing the potential provides the impetus to construct self-fulfilling prophecies to try to nurture it - albeit always imperfectly because of the inherent 'naturalistic fallacy'.

The economic floodplain management decisions are then required to be based on available information to guide the ideal-seeking process, including information as to what the ideal process is, what goals define it and what means operationalize it. The goals can be formulated in terms of rules to follow and so an economic analysis may be formulated in terms of rules. To the extent to which these rules can be assessed as to whether or not they are fulfilled by technical analysis, and also whether the rules themselves can be integrated together by information technology, then economic analysis can be developed as a rule-based Expert System.

Economic theory available as a tool for use in floodplain management needs to be

critically reviewed in light of its ability to fulfil the above requirements. Such an attempt to do so is a critical development within the tradition of economic analysis; itself having a history of socially constructing the economic processes it has attempted, and attempts, to describe and improve. Critical analysis has always been carried out throughout the history of the tradition and serves as the basis for the analysis here. The major critical economic traditions within the Western economic tradition and the fundamentals of the classical theory, serve as the necessary basis from which the overall approach and specific reconstruction for contemporary floodplain management are developed.

Firstly however it must be recognized that all human cultures have economics in the sense of mentally formed guides for the interactive use of resources. These must be understood within their own paradigms or worldviews and the western one at present cannot logically be applied to cultures which do not hold the fundamentals of the Western Enlightenment worldview. Now that worldviews other than that of the Enlightenment are of interest to those who traditionally have been operating within the Enlightenment worldview, it is important to explicitly avoid analysing all economics from within the Western worldview. Specifically, traditional Western worldviews because of postmodernism, and in the Aotearoa/New Zealand context Maori worldviews, are of special interest. This is having a beneficial effect on helping the Western economics tradition reflect on its assumptions which are based on fundamentals of the Western Enlightenment worldview. As in all fields where postmodern reflection is operating, the fundamentals of the worldviews, assumptions and axioms giving rise to the theories stemming from the Enlightenment, are under increasing question. A consequence of this is the attempt to develop a basis for economic theory that is universal without essentializing; i.e. can transcend different worldviews. Using as a basis the social theory developed in Chapter 4, an attempt is made here.

The critical developments discussed are: Post-Keynesian, Marxist, Postmodern and Ecological economics. Firstly however an outline and deconstruction of the classical tradition is made. After review of the critical traditions an attempt at reconstruction is made. Then the specific aspects of the reconstruction are applied to floodplain management.

## **8.2 CLASSICAL AND NEO-CLASSICAL ECONOMIC THEORY**

The paradigm in economic theory that stemmed from the Western Enlightenment was catalyzed by Adam Smith in the publication of his book 'The Wealth of Nations' in 1776. His book formalised an approach to economic activity that had begun to become a

socially acceptable activity. Before his work, the theory that was formally held was that promoted by Medieval Christianity, formalised by Thomas Aquinas in the thirteenth century (O'Connor, K 1993).

Smith's work was a normative theory reflecting various features of the Enlightenment and Renaissance preceding it (Fromm 1942). Central was the affirmation of individual rights of choice. However this became separated from the contextual issues, which the Middle Ages had developed highly into a metaphysical scheme (Toulmin 1982). Instead of individual choice being based on how to better fulfil intrinsic values through cooperating with the operation of grace ordering the whole universe including human society, it became based on how to better fulfil the use of a 'disenchanted' objective world which was 'dreadful' rather than grace-filled (Fromm 1942).

For Smith the way to improve society was to improve wealth and the way to improve wealth was to appeal to the potential in humans for self-interest and to deem it a virtue rather than vice, i.e. there was a distancing from the metaphysical holistic principle of cooperating with the impetus of divine grace. A quote used by Schumacher (1973:p24) gives a clear sense of the thinking Smith set into place as the language game for western economics. It was taken by Schumacher from a paper by J M Keynes who critically developed Enlightenment economics but without challenging this aspect of it:

'For at least another hundred years we must pretend to ourselves and to everyone that fair is foul and foul is fair; for foul is useful and fair is not. Avarice and usury and precaution must be our gods for a little longer still. For only they can lead us out of the tunnel of economic necessity into daylight again.'

Formalised as a normative theory this worldview and the structural power relations that emerged from it became dominant. Fromm (1942) gave a seminal analysis of what the structural power relations were in terms of psychology. He argued that the breakdown in the Medieval worldview and social organisation led to increased insecurity as entrepreneurial activity became legally possible (see Toulmin 1982 also). With this came a shift in metaphysical assumptions with the Protestant religious change in worldviews even removing grace from Nature. Fatalism in face of a dreadful world became to be accepted as the appropriate attitude (see Chapter 3). Social structure paradoxically became an absolute. Along with this change in worldview at the religious level, the disenchantment of Nature from the Enlightenment and the classical physics of Isaac Newton led to the making of the Is-Ought fallacy in use of Smith's ideas.

Whereas Smith's ideas were explicitly normative his views became essentialized and used to describe human nature and social interaction. This was intellectually possible because of the work of Hobbes which promoted the idea of the nastiness as well as the dreadful reality of Nature; including human nature (Schwartz 1986). Also Darwin's work argued for the centrality of competition in the metaphysics of Nature. This has been continued until recently through the development of behavioural psychology (see Pepper 1984 and Schwartz 1986 for critical reviews).

With the essentializing of human nature to be selfish and competitive, rules were sought which fitted in with the mechanistic worldview of the Enlightenment based on the exclusive use of the causal metaphor and using Newton's classical physics as the paradigm because it had begun to prove itself so effective in the physical world. Peet (1988: p25) has given a clear statement as to what this may have involved.

'When the wise men of the 17th Century looked at the well-ordered world of Newtonian mechanics, they could hardly fail to compare it with the muddled, chaotic world of the activities of people in society. The erratic behaviour of people, and the imperfect workings of government, did not square with the reliable, timeless, predictable world of Newtonian celestial mechanics. Their dilemma was quickly resolved if society was not behaving in the same kind of way as the universe, then the logical explanation was that people in society were not keeping to the natural laws that govern that same universe.'

With this development 'classical' economics was born. It was (is) a theory which is often accepted as descriptive rather than normative and thus making the Is-Ought fallacy.

Interpreters who recognise the normative form it has are able to seek to implement the analyses where the consequences may be beneficial. However the uncritical application of it through the making of the Is-Ought fallacy has led to negative consequences through promoting individual self-centredness and competitive interactions, while treating Nature (including other humans) as objects for use. The negative consequences were first commented upon in the effect on society and now more recently in the effect on the environment and ecology.

Even though the negative consequences seem to contradict Smith's normative intentions, because it is a theory which has dominated economic thought (Smith was the first formal 'economist'), it is very difficult for a practising professional without formal and critical economics training to be able to find and apply a recognized economics

methodology which does not still promote uncritically the goals of Smith's theory.

Therefore the application of economic theory to floodplain management attempting to apply ethical principles has required a critical review of the economics discipline to be carried out, along with an attempt to reconstruct an economic theory that is consistent with the ideals values and goals being sought in floodplain management outlined in Chapter 3. It is not possible to obtain textbook guidance on this.

### **8.2.1 Outline of Classical and Neo-classical economic theory.**

The first thing to recognise is that classical economic theory has vastly narrowed the class of social activities that are deemed to be economic. According to The Shorter Collins English Dictionary (1993) economics means:

‘The social science concerned with the production and consumption of goods and services and the commercial activities of a society.’

Traditionally economics was described rather by a collection of normative rules about how to behave in a household. This included rules about appropriate social relations between people and with the rest of Nature, often based on theological principles (Schwartz 1986 and O'Connor, K 1993). Classical economic theory narrowed it down to mean the trading activities of the market. All else came to be ‘externalities’ to the economic process. Externalities have been defined as (Arrow 1994: p5):

‘Social interactions not mediated by the market.’

Because of this, how externalities are considered in economic theories serves as a touchstone for reconstruction of them. Not surprisingly the rest of social activities formally excluded by economic theory has ceased to be seen as important. Never-the-less because they still had an affect they were interpreted as types of self-interested competitive behaviour within markets. Thus classical economic theory came to be a very abstract formalisation. Unfortunately because of the making of the Is-ought fallacy the consequence was the nurturing of self-interested competitive trading behaviour outside of trading institutions. It even became formalised as the basis for all decision-making (behavioural decision-making, see Chapter 9).

### **8.2.1.1 Core concepts.**

Four core concepts present in classical economic theory are focused on here as they are relevant for the later critical review and reconstruction. They are the concept of autonomous individuals, the market, the concept of equilibrium and the role of money.

#### **8.2.1.1.1 Autonomous individuals.**

As mentioned above this has its roots in the concern for individual rights stemming from the Renaissance. However within the Enlightenment worldview it became defined in specific ways which are now seen as problematic by many.

Firstly there was the rise of empirical realism which was a response to Hume's recognition of the difference between the descriptive and the normative. According to this ontology and epistemology facts were observed phenomenon and able to be given mathematical formulation, while values were purely subjective experience. In the formulation of classical economic theory values came to be concerned with the free choice 'valuing' utilities. Other types of valuing were not considered. This is consistent with the Enlightenment worldview which saw Nature as merely objects for use. Also the valuing process was seen as relative and so ethics and hence spirituality came to be outside economic concern. Also because economics (defined as trading) was seen as referring to all social interactions, it meant that ethics and spirituality came to be considered as outside of the realm of pertinent information for economists, even though economics claimed to be concerned with human values. Thus ethics and collective responsibility became to be considered as an externality. This approach has been termed 'methodological individualism' (Arrow 1994) as already reviewed (see Chapter 4).

As well as the narrowing of concern about the valuing process, the making of decisions based on individual choice maximising self-centred utilisation came to be interpreted as 'normal'. 'Rational' decisions came to be considered those which maximized self-interest in terms of the utilities defined by the individual. These came to be called the axioms of 'economic man' (Hollis and Nell 1975). From this abstraction, Game Theory was developed which logically explored what the expected collective implications would be based on individuals making 'rational' decisions (see Chapter 9).

Game theory did/does not though restrict itself to concern for competitive interactions between individuals. It explores the possibilities of cooperative rules which may end up more rational in the long term for 'players'. But only for self-interest. However there has also been a strong emphasis in classical economic thought to focus on competitive interactions. Competitive attitudes, as mentioned in Chapter 5, are an

expression of the application of negative freedom which necessarily objectifies those/that being competed with. In doing so there has been the nurturing of the consideration of other human beings being engaged with in social interactions as objects to be used for maximum utility.

#### **8.2.1.1.2 The Market.**

The market is a social institution allowing for trading to occur. Symbolic exchange using money to represent utility (usually given standard values but not necessarily) is carried out to ease the distribution of goods that become exchanged. Habermas (1971) characterised a market as the concern for reciprocity, i.e. with the exchange of goods in an equitable way. As such it is a cooperative activity of social interactions to fulfil the goal of the distribution of goods throughout the community. This can be interpreted as the social role for the market institution.

The classical economics approach based on the normative view of Smith has sought instead however to encourage competitive activity and 'rationality' in individuals because of the belief and theory arguing that it will produce the most 'efficient' distribution of production. Then with the making of the Is-Ought fallacy it came to be defined as what a market is. Consequently instead of seeking to focus on how to achieve the appropriate social goal of distribution of resources, the focus came to be that of individuals maximizing their obtaining of money through the exchange process (making of profit). Money ceases to be only a means for distribution between the community even if this is the formal rationalisation for it. The rationalisation becomes convoluted and incoherent as the quote by Keynes above shows.

The theoretical emphasis on efficiency as a normative guide has been due to the emphasis on the need for creation of wealth in face of scarcity. The work of Malthus emphasizing scarcity of resources and the problem of human population growth was an important influence during the formative time of the development of classical economics (Pepper 1984). The point that must be remembered is that it is scarcity in a 'disenchanted' world where consumption was/is seen as the only source of 'meaning' or 'happiness'.

#### **8.2.1.1.3 Equilibrium.**

Equilibrium as a concept is how classical economics incorporated the classical physics view of timeless laws into theory. The action of competitive markets with 'rational' individuals was/is modelled as an equilibrium in the long term. The equilibrium was/is described in terms of distribution as a balance of supply and demand. A

consequence of the abstraction of an equilibrium is that economic processes are assumed to be ergodic - another indication that a timeless model is implemented.

The concept of equilibrium came to be the goal that an as yet imperfect market was heading toward, just as long as it was allowed to achieve it. Thus it came to have utopian connotations. It has come to serve as a symbol of eschatological meaning (see Chapter 3).

Interestingly initially the abstract concept of equilibrium was not postulated, but rather the metaphor of an 'invisible hand' was used to 'describe' (claim) how the results from a competitive market would produce the best results.

#### **8.2.1.1.4 The role of money.**

Money as a symbol to help in the distribution of resources was expected to act as a representation of the utility of the good being supplied. This was modelled as being a neutral sign. Money was modelled as only having this role of signification. It was not considered to have a role or value in itself. Exchange value is seen as a significant value (see Chapter 3).

### **8.2.2 Criticism of the classical economics tradition.**

Criticism of classical economics was largely developed by the critical traditions that emerged in response to it and outlined in later sections therefore only brief outlines are sketched here. The four core concepts outlined above are used to focus the criticism.

#### **8.2.2.1 Criticism of the concept of autonomous individuals.**

Criticism of methodological individualism proceeds along the lines of outlining what externalities are ignored. As already mentioned this includes the issues of ethics and spirituality. However it is also concerned with the rules which people obey so as to be society - the language games that structures society. These structural power relations are not recognised by the abstractions involved in Game Theory. Arrow (1994) argues that it is important to consider the actual rules that order society and not only abstractions as to what the rules are. The abstractions act as a game themselves and so attempt to change the games as a self-fulfilling prophecy and normative theory.

#### **8.2.2.2 Criticism of classical understanding of the market.**

Arrow (1974) also pointed out earlier that the concept of a market is also an abstraction and is socially constructed rather than existing naturally. Markets do not exist



when business is entered into. They are created by the business activity and governing authorities. However classical understanding based on the notion of an equilibrium and ergodicity in peoples' choices perceives markets as timeless natural (supernatural) entities. They are symbols of immortality (see Chapter 3).

Schwartz (1986) makes the point that for markets to exist certain rules by players need to be observed, e.g. being honest (to some degree anyway). So a market is not a natural event (or supernatural) which produces good consequences by the operation of an 'invisible hand'. It is a social institution constructed and maintained by a specific 'language game' of structural power relations. The externality not recognised here is that of social planning and existence of social institutions.

The consequences of allowing and encouraging social institutions of a competitive market by classical economic theory, thus allowing and promoting the accumulation of profit or capital (exchange value), are severely criticised, especially by Marxian commentators (see Section 8.3). A competitive market is considered by this criticism to be an inappropriate set of rules on which to base social relations. Accepting this criticism necessitates further consideration as to what rules are required to allow a non-competitive market to operate. This is carried out in Section 8.6.

Because a market is a social institution involving planning to construct it, this externality also implies that the externality of information is required to carry out the construction of a market (Arrow 1994). There has to be understanding of the effects of activities - basic ethical concern for consequences as well as scientific concerns for consequences; environmental and ecological.

### **8.2.2.3 Criticism of the concept of equilibrium.**

Arrow (1974) points out that the fundamental notion of an equilibrium occurring in supply and demand is incoherent because (at the time of his writing) no adequate explanation of the mechanism for the communication between players required to produce it had been developed. The abstraction of an equilibrium as the end point of economic activity may lead to consequences different to those if an understanding of the actual mechanisms present are understood (e.g. Dalziel 1994).

Faber and Proops (1986) point out that the notion of general equilibrium as an abstraction is limited in use, even if expected consequences through using it as a model are the same as one based on underlying mechanisms, because the physical, biological and ecological reality economic activities occur within are not at, or even tending toward, any general equilibrium. Rather economic activity is in a co-evolution which is an irreversible

and indeterminate trajectory. Therefore the fundamental error is to accept it as an immortal symbol.

If the abstraction of an equilibrium is to be useful it needs to be only used in specific contexts in which it is a valid and helpful abstraction. It can only be for limited periods and specifically constructed institutions. Never-the-less the concept of equilibrium generally has a place as an abstraction as it occurs in both sociology and ecology to describe states of relative stability within the co-evolutionary process. The task is to determine what contexts allow for the helpful implementation of the concept.

What has to be avoided is belief in a real ergodic process of competitive interactions between rational individuals, or imperfectly rational individuals in an imperfect competitive market not yet fully under the sway of the 'invisible hand' which naturally (or supernaturally) produces an equilibrium. The second part of the last sentence alludes to the neo-classical view. It admits lack of perfect rationality, however still believes in the utopian view that if the possibility of an equilibrium is encouraged the best consequences will result. Therefore social planning is allowed, but only so as to further the natural (or supernatural) action of the 'invisible hand'.

Schwartz (1986) points out however that market institutions have ironically been put into jeopardy through the neo-classical encouragement for them. He argues that the rules of conduct required for a market to work are being eroded by the increased encouragement of self-seeking and creation of markets. Too much dishonesty is being nurtured. The self-imposed blindness to externalities is having an ironical twist to it as can be expected because second-order feedback is being ignored (see Chapter 4).

#### **8.2.2.4 Criticism of the role of money.**

Criticism occurs around two main aspects. Firstly it focuses on the objectification occurring with the process of using symbolic exchange, i.e money to represent the utility measure of something. Reciprocity without the use of money does not alienate the receiver from the giver. It is an interaction between subjects. However the use of money enables impersonal exchange to occur. This is not however a necessary consequence of the use of money as long as reciprocity is still what occurs. But when competition occurs in a trading situation, aided by the use of money, objectification and resulting alienation becomes the norm because of the expression of negative freedom (see Chapter 3). As mentioned above, it involves not only objectification of non-human Nature but also other human beings as well. It is commonly termed commodification. Neo-Marxian and Postmodern commentators focus on this aspect of money (see Sections 8.3 and 8.4).

A second focus is on how money is not in actuality neutral as is assumed in classical theory. It is not neutral because it is created and controlled to an extent by financial institutions which accordingly have real power to affect social interactions. The accumulation of exchange value, distinct from utility value, as an end in itself is the consequence of Smith's normative theory, and does not therefore even necessarily supply necessary resources.

### **8.2.3 The application of classical and neo-classical theory in public policy.**

There have been three main approaches used from within the classical/neo-classical paradigm: utilitarianism, arguments based on efficiency and libertarianism.

Utilitarianism was initially the basis for policy on economic decisions. The holism of utilitarianism allows only one objective to be considered, which was to increase overall wealth. Initially this was able to be interpreted as an ethical attempt to extend the moral community beyond a small elite. However it came later to be seen as being used rather to justify the injustice that occurs through making profit using the work of others to increase the value of production. Marxian analysts made this point. For them the distribution of wealth was important as well as the overall wealth produced. Therefore a single objective was not considered adequate (see Section 8.3).

Some arguments based on 'economic efficiency' attempted to be multi-objective in some developments of it. Every player was considered to be an end. Cost-Benefit-Analysis (CBA) emerged from this approach (see Section 8.2.3.2).

Libertarian arguments have formed the basis for more recent arguments (Arthur and Shaw 1978). This involves an explicit adopting of negative freedom. There is the claim to the right to be free from social obligations apart from that of not interfering with others' right to the same. In light of the point Schwartz (1986) made about the breakdown of markets, it is hard to comprehend how such a point of view can be expected to be maintained. Without sets of rules enabling coherent social relations, which necessarily involves obligations, a system does not exist. It appears to be simply blind faith in the eschatology symbol of a competitive market or 'invisible hand'.

#### **8.2.3.1 An axiomatic approach to public policy.**

As well as the attempt to use ethical theories to apply classical economic theories for policy-making there has been the attempt to deduce ethical normative guides for public policy from the axioms of the classical economics canon.

The attempt began with a consideration of uncertainty. This was concerned with

individual rationality. However it came to focus on public policy concerned with individuals.

McClennen (1981) has reviewed the research programmes concerned with it. It began in the 1950s. A negative result appeared which said that there could not be a rational decision rule for choice under uncertainty. Attempts were made to resolve this negative result. They involved dropping one or another of the conditions which collectively are inconsistent with the assumption of the existence of a decision rule for choice under uncertainty.

A little later another research programme led by Arrow (1963), considered whether rational public choice is possible. This came to be applied to the attempt to define a 'social welfare function' which weights elements in a utilitarian analysis. Mathematically the two research programmes are equivalent (see Chapter 9).

The second negative result has been attempted to be resolved by 'enriching' the information available to individual's ordering in such a way so as to permit inter-personal comparison (either ordinal comparison of levels of preferences or cardinal representation). This is equivalent to dropping one of the conditions producing the negative result. Both programmes came to similar positive results with both results accepting either an unweighted average utility of the participants, or exclusive concern for minima or maxima.

These two possible positive results for the research programmes into individual and social rationality have two proponents:

1. 'New' Utilitarianism.
2. Rawls' theory of justice.

#### **8.2.3.1.1 'New' utilitarianism.**

This tradition has been based on the development of Bayesian probability theory and that of subjective probability (see Chapter 5). Harsanyi (see McClennen 1981) has developed this and proved for both individual rationality in the face of uncertainty, and for a social welfare function, that an unweighted average utility is the solution. It is based on the set of axioms for these two rational choice situations. Those of 'economic men' optimizing expected subjective utility. The comparability of utilities has only to be ordinal. However cardinal ordering also produces the same result. Representation is usually given through the use of monetary values obtained from betting games (see Chapters 5 and 9).

### <sup>2</sup> 8.2.3.1.3 Rawls' 'Theory of Justice'.

Rawls (1971) takes the opposite approach and stresses the need to try to model a decision process that is considered moral by competent moral judges. Rawls suggests that an appropriate 'theory of justice' can be determined by assuming and promoting radical uncertainty; where there is a 'veil of ignorance' about what is the social state of an individual state. Thus existing social privilege that may bias opinion is attempted to be overcome.

Firstly a lexical ordering of utilities is assumed to be made in contrast to the assumption of commensurability between all values which leads to the utilitarian result. Only distinct levels of utilities are able to be ordinally compared. It is applied to individual rationality as well as about social rationality. Incommensurability between some options is assumed, thus not allowing any weighing up or compromise to be made (including about risks). Therefore there is an unwillingness to bet about the future. A 'play safe' attitude is modelled.

The consequence of rationality under a 'veil of ignorance' is to make sure that the first priority level has the minimum maximized, and only if there is a tie, to go to the second priority and so on.

Criticism of utilitarianism makes the point that such lexical ordering does exist and so needs to be modelled (Tribe 1972 and Schrader-Frechette 1985b). Such an ordering is expressed for example in the differentiation made between needs and wants (see Chapter 9).

### 8.2.3.1.3 Criticism of the axiomatic approach.

McClennen (1981) makes some valid critical comments. He concludes that the 'New' utilitarian approach argues modus ponens from axioms about what rationality is, to what is ethical for social rationality, where this is not the only way of arguing (see Chapter 5). He only points out that it is just as logically valid to argue modus tollens from moral philosophy's criticism of utilitarianism that the axioms of rationality for 'economic men' are wrong. McClennen did not develop his point however to also point out that the modus ponens argument makes the Is-Ought fallacy.

The modus tollens approach is that made by Rawls and does not make the Is-Ought fallacy. It allows for consideration of what human activities should be encouraged so as to promote ethical behaviour. However the adopting of Rawls' approach by the research McClennen reviewed attempts to rationalize it modus tollens through the relaxing of one of the conditions.

The attempted rationalisations of both utilitarianism and Rawls' theory of justice are inadequate however because moral philosophy seeks some ethical theory in between the two when considering the situations described. These two theories may never-the-less form the poles in which systematic analysis of aggregation of discrete values can be carried out (see Chapter 9).

McClennen also raises the question about the research programme's results into uncertainty because of the two very different solutions which appear depending on which assumption is held. It is a 'brittle' result. He is critical of deeper assumptions which are related to methodological individualism. This is developed further in terms of the consideration of rationality where there is uncertainty in Chapter 9.

Kneese et al. (1982) have reviewed various ethical theories which could be used to decide upon criteria for the ordering problems raised by arguing *modus tollens*. They conclude that no measure is intrinsically better than any other, and that all may have valid applications. Shrader-Frechette (1985b, 1987) has incorporated these results in a critical review of the use of CBA. CBA has been the main attempt to implement economic analysis in public policy.

#### **8.2.3.2 Cost Benefit Analysis (CBA).**

Traditionally CBA was a measure of social welfare involving the use of an unweighted utilitarian analysis, as suggested by Harsanyi, and gives rise to 'New utilitarianism'. Technical risk analysis was used to incorporate uncertain future events (see Chapter 6), but usually with discounting of future events, to model the need for return on capital investment and future uncertainty.

However the justification for the use of a utilitarian analysis is not usually that of 'New utilitarianism', nor even arguments from moral philosophy arguing for utilitarianism, but rather from a consideration of an 'economically efficient' solution for multiple objectives.

Where there are multiple objectives, e.g. the maximization of utility for several players, a commonly defined moral policy is to seek a 'Pareto efficient solution' where no one person's increased utility will decrease any other person's (e.g. Schofield 1987). The aim is to maximize the multi-objective utilisation of resources. It is an example of a solution in between an unweighted utilitarianism and the Rawlsian criterion.

However there is no unique solution. At best a 'non-inferior' set of 'undominated' alternatives can be found.  $u^*$  is a non-inferior solution to the set of objective functions  $f_j$ ,  $j=1, \dots, n$  seeking maximisation if:

$$\nexists u \neq u^* : f_j(u) \geq f_j(u^*), j=1, \dots, n \quad (8.1)$$

$$\text{and } \exists j : f_j(u) > f_j(u^*), j=1, \dots, n$$

A 'Pareto improvement' can be made when an alternative can be 'dominated'. Viable public policy alternatives are considered to be those that are undominated.

The rationale for CBA involves a development of this by considering 'potential Pareto' solutions. Here Pareto improvements are considered which would require compensation by players benefitted to players disadvantaged in such a way that it still leaves the benefitted better off. Mathematically this is the same as utilitarian analysis.

#### 8.2.3.2.1 Criticism of CBA theory.

The difficulty is the issue of compensation. As Schofield points out, it is usually simply not done. When it is not done the policy is exactly equivalent to an unweighted utilitarian policy. The reason is because the attempt to carry out compensation is problematic. There is a cost associated with compensating over and above the actual compensation which is not generally considered in CBA. Therefore if compensation is attempted the solution may not be optimific nor even have a net benefit.

Compensating is also socially problematic because the paying of compensation by those benefitted is often not seen as compensating for benefit gained at others' expense. For example libertarians would interpret it as stealing on the part of a Council or Government when attempts are made to levy with taxes for this effect.

In floodplain management however compensation is sometimes carried out if it involves relocation of people. Also it is attempted to be included into a CBA. But the issue then arises about how to calculate the required compensation. To base it on individual valuing can produce problematic responses. For example if there is sheer refusal to be relocated in effect an infinite value is placed on the existing location. The consequence is that no CBA of possible alternatives other than to not relocate would give a net benefit. Also the issues relating to achieving consent reviewed in Chapter 6 apply.

The deeper issue is however why compensation is attempted at all instead of seeking Pareto efficient solutions. The reason seems to be for ease of procedures. Though some critics argue that there are also ideological reasons (e.g. Kennedy 1981 and Zinke 1987). But once again the situation only arises because methodological individualism is assumed. If it was not then other information could be used to help attempt to find a solution, e.g. dialogue between those concerned.

More perceptive analyses pick up on the findings of the research into uncertainty

and Arrow's negative result, and argue that any attempt to apply syntheses of utilitarian and Rawlsian approaches to CBA is inherently dictatorship by an analyst even if it is based on the very best moral philosophy (Blaug 1980). This also points to a fundamental incoherence in classical theory, developed in Section 8.3, between the values the moral analyst has and those they are modelling as shown clearly in the quote by Keynes used by Schumacher. In response neo-classical theorists argue that the moral thing to do is to let the market through the operation of the 'invisible hand' make the decisions. See Bromley (1990) for a review of the issue.

Schrader-Frechette (1985b, 1985c, 1987) has also been rigorously critical of the incoherence, yet concluded that some synthesis to form 'ethically weighted CBA' is the appropriate methodology. Schrader-Frechette (1985b) concludes that it has to be remembered that economic analyses are only tools and so should not be discarded unless better tools are able to replace them.

Schrader-Frechette (1987) explains that the real fault in CBA is in the lack of appreciation of how to use it with its deficiencies. She adds that the reason it has deficiencies is because of the inability to take externalities adequately into account. She argues that the use of weighting as carried out in social welfare functions and the inclusion of non-market evaluation and other consent procedures in the attempt to include externalities are all positive steps to make the analysis a better tool. She stresses however that the information as to what the weighting should be is an externality and so outside of the market. Therefore she resolves Arrow's negative result in the opposite way to neo-classical theorists by arguing instead that non-market institutions should be used to determine them. She suggests that it should involve the legal processes of submissions and courts (Schrader-Frechette 1985c). A more consensual approach is suggested in Section 8.6 while recognising the validity of her remarks.

### **8.2.3.3 Efficient taxation method.**

Another suggested method for public policy is that governing authorities instituting the market should levy taxes on groups which have detrimental effects on others, e.g deforestation in catchments of a floodplain. This is aimed at 'biasing' the market thus producing an equilibrium in supply and demand where the cost for the supplier (e.g (de)forester) is 'artificially' high. Others describe the process as expecting all to pay for their total costs. Externalities are attempted to be taken into account in how the market institution is instituted. However no less than in the attempt to seek compensation explicitly within a CBA, the imposition of such tax is interpreted by Libertarians as



unethical. Also it only exacerbates the incoherence of the theory.

Another argument is that education will produce the same result by changing the demand and so taxes will become unnecessary. However education involves the explicit inclusion of the externality of information and so goes against the 'spirit' of the neo-classical approach.

In practice it is found that when 'artificial' controls are implemented the market can begin to fail because 'black markets' or 'underground' institutions are formed. Once again the point Schwartz made about the irony of competitive markets is relevant. To be coherent it is necessary to explicitly face the externalities through education and/or forums allowing discussion and cooperative agreement to emerge.

#### **8.2.3.4 Conclusion**

The main point coming out of the review is the need to explicitly include externalities into public policy economic concerns. The fundamental definition of economics by the classical tradition as trading in a market is found to be inadequate and in need of change. The challenge is to consider how to better take externalities into account. Review of other economic theories helps gain insight into this.

### **8.3 POST-KEYNESIAN ECONOMIC THEORIES**

Even though post-Keynesian theory is not historically the first critical development of classical theory reviewed here it is the closest to it and so included first.

Post-Keynesian economic theory criticises the neo-classical model of a market tending toward equilibrium and the normative claim that a market should only be 'interfered' with to maintain the operation of the market. An attempt is made to both consider externalities and the real 'mechanisms' involved in economic activity rather than relying on the abstraction of a market at equilibrium to direct policy. The empirical realist basis for classical economics is replaced with a transcendental realist position as held by Bhaskar (1978) (e.g. Dalziel 1994). In doing so methodological individualism is also rejected in favour of consideration of entities involved in causal processes, i.e. where the causal metaphor can be applied. Entities in general are collective and individuals are a special case of these. Entities can be institutions including financial institutions. Therefore externalities associated with social organisation of institutions are considered. Accordingly the neutrality of money is not assumed.

However a classical mechanistic worldview from the Enlightenment is still held because of the exclusive use of the causal metaphor. The difference with classical

economics is that methodological individualism essentializing human nature and making the Is-Ought fallacy is however avoided. But the use of transcendental realism assumes that the entities involved in the mechanism are still never-the-less 'hard' in the sense that they can be defined and do not change for the period of analysis. Therefore the paradoxes arising out of self-referential systems and ontological systems of reflexivity are ignored.

A correlate assumption is that the system of economic interactions can be analyzed as a closed system so as to determine what the mechanisms are and how they behave, even if in real systems they may be open to varying degrees. Both assumptions are problematic.

A realist recognition that economic activities are irreversible and indeterminate is accepted and so the externalities involved in the interactions involving change, and in the externality of knowledge defining them, are appreciated and incorporated. Because of this ergodicity is not assumed. Davidson (1991) even argues that sometimes probabilistic analysis cannot be made at all about future possibilities. He argues that in many cases 'we simply do not have a clue.' Real systems may be very open. Generally however there is the attempt to use a causal metaphor so as to apply standard predicate calculus involving differential equations (Eichner 1983). These can however be expected with certain sets of differential equation to be chaotic and so indeterminate no matter what degree of closure may actually be able to be modelled.

### **8.3.1 Application of Post-Keynesian theory.**

The aim in understanding the supposed real mechanisms in economic interactions is to better manipulate or engineer the processes to produce specific goals that are considered appropriate. For example a 'civilised' society (Davidson and Davidson 1988). There is no utopian view that any particular strategy will produce them, or that some specific result is in the long run inevitable. Rather it is considered up to the ability of the economist to understand and to help guide managers, planners and policy makers and all of those with power to direct the evolution of economic activity. This is however problematic on two accounts and is due to two assumptions.

Firstly, as neo-classicists point out, if the process is chaotic no amount of engineering will allow the economist and governing authorities to direct the path the economy takes. Lavoie (1989) hence argues that it is better to leave it to the market of the 'invisible hand' to produce the best result. Postmodernists argue that it means that the mechanism (sic) has to be changed by recognizing the self-referentiality of the systems and hence creativity always present, i.e they reject the first assumption. The use of the causal

metaphor is not essential (see Section 8.6).

Secondly, the extent to which mechanisms are able to be discovered and that manipulation of them is possible is very problematic. The second assumption has implicit in it the view that economists dominate the situation (in the sense Weinberg (1975) uses the term), i.e. that economists know more about what the economic interactions are than anyone else. It is assumed that others behave predictably to the economist and that the economist does not to the others. Further if the economist relies on enforcing the implementation of institutions to have a causal affect then it is domination in the ordinary sense of application of power. The existence of indeterminacy could be interpreted as suggesting that it is the assumption of dominance that is wrong rather than that the situation is chaotic. It may be possible to observe some trends to an extent, but there is always the possibility that the entity having its activity determined may adapt creatively and fool the observer and manipulator. Freedom and creativity are latent in any social situation. The detached observer needs to reflexively consider what their part in the mechanism could be other than as a manipulator from outside, and what the 'mechanism' could be.

The last point raises the first assumption again about the unchangeableness of entities involved in mechanisms. Language games may in certain cases be able to be described by the causal metaphor but they are still created by the creativity of people. Thus the mechanisms are socially constructed. Further they exist primarily as systems of structural power which are based upon collectively held worldviews of unreflected upon learned activities. So the economic behaviour observed is likely to be to an extent an expression of normative views about what it should be. This would have been instituted by some economic theory in the past either explicitly or otherwise. What the Post-Keynesian approach fails to recognize explicitly is that any mechanism which may exist will be open to insight about new views, including those of the Post-Keynesian. If these views do become part of the process then indetermination would result as the system would be self-referential. If this occurs then the normative goals that the Post-Keynesian has will simply be operating as a directive. This may achieve the result that is wanted, or there may be a reaction to counter the aims of the economist. Post-Keynesian theory does not distinguish between ethics and goals nor is it aware of systemic responses when ethics is not used to inspire directives. The consequences are therefore not necessarily going to be the desired ones based on analysis of the mechanism any more than a utopian belief in an equilibrium and competitive market would expect.

However as described in Chapter 4, when self-referentiality is appreciated a process

to attempt to achieve goals is able to be found. Moral freedom expressed as free-willed cooperative agreement to aim to achieve goals mediated by trust and rational discussion so as to be integrated into the systems hierarchy can then be sought and can be expected to be stable as long as second-order feedback is continued to be listened to and monitored for.

#### **8.4 MARXIAN AND NEO-MARXIAN THEORIES**

Marxian analysis is based on concern to use resources for the social good (Kellner 1989). It has an explicit normative intent to seek to achieve justice in the way resources are used and distributed. In the attempt to do this there is a focus on structural power and hence worldviews of learned behaviour and consciousness. But just as classical economics was/is limited by its formation within the worldview of empirical realism and classical physics, Marxian analysis is limited by its formation from within the Hegelian tradition of philosophy as well as the Enlightenment (see Chapters 3 and 4).

Marxian analyses assume a deterministic process of evolution through conflict. Whereas for Hegel this was evolution of consciousness itself (absolute idealism) for Marx it was consciousness conditioned or even formed by the economic conditions of the individual due to structural power relations. Thus through processes of contradiction in economic activity leading to conflict and changes in economic structure, consciousness also changes. The process of change was/is seen to be a deterministic one that always leads to improvement. It is a utopian view with the belief that eventually injustice will be overcome through the unfolding of the evolution of history. It is also fatalistic as there is seen no way to avoid the injustice and conflicts on the way. It is the deterministic aspect of Hegelian philosophy which is problematic. Other features, especially the dialectical method are heavily drawn upon by postmodern critics of Marx.

Truth is seen to be relative to the state of consciousness of the class in its state of partial enlightenment within the evolution of consciousness. As mentioned in Chapter 4 it is 'naive relativism' as Marxists are perceived as having an absolute view and are able to see the ignorance of all others (see Chapter 4). Marxian analysts assume, as do post-Keynesians, that they dominate the system. The difference is that for Marxists the manipulation or engineering is carried out in an explicitly political way because the governing authorities are seen to be part of the evolving process. The domination explicitly involves the expression of power to cause conflict and revolution of structural power.

Central to Marxian analysis is the concern with ignorance termed 'false

consciousness'. Marxian analysis adopts a hermeneutic of suspicion (see Chapter 4). Marxists argue that the way that the economic structures are maintained is by ignorance that is being imposed through ideological coercion through how the process is described by governing authorities. The description by the governing authorities is itself seen to be an expression of the ignorance of those belonging to the governing authorities; the privileged class. The focus in Marxian commentary is to point out incoherence in economic analysis through a hermeneutic of suspicion. However they are not content to point out that it is an expression of ignorance and falsely held by all (privileged as well as disadvantaged). Because of their belief in the Hegelian deterministic process, and their own transcendence of it, they aim to promote conflict in the attempt to improve both consciousness and the economic structures. In doing so they posit the need to express negative freedom which objectifies other humans no less than classical theory does. This is perceived as possible because the essence of the process is considered to be material.

They attempt to carry this out by interpreting the situation as a class struggle between the privileged 'oppressors' and the disadvantaged 'oppressed'. Marxian commentaries are narratives based on the theme of conflict between the oppressors dishonestly coercing the oppressed through the use of rationalisations of their behaviour. The aim of such interpretations is to politicise the 'oppressed' so that they act to change the existing economic structures which according to the theory will also enlighten consciousness (of everyone).

Thus in Marxian criticism of classical and neo-classical economic theory, analysis points out incoherence in theory and interprets it as masks rationalising oppression by privileged classes. Classical and neo-classical economists are interpreted as being intellectual collaborators of 'Capitalist oppression'. Subtle arguments describing how the system privileges those who support its oppression explain why classical and neo-classical economists have gained the prominence they have in modern economic thought.

#### **8.4.1 Examples of Marxian analysis.**

Four examples are given. They are chosen because they bear upon the issue of floodplain management and are helpful deconstructions of incoherence of classical/neo-classical theories.

##### **8.4.1.1 On methodological individualism.**

As in post-Keynesian analyses collective groups are seen as entities for economic analysis. For Marxists however methodological individualism is an ideology prompted to

mask the structural power creating injustice. The argument is that when the 'oppressed' are seen as free individuals having choice then the structural reality of groups creating markets and choices through advertising is obscured. The result is 'false consciousness' (see Chapter 4) which is described as 'commodity fetish' and is interpreted as a means to placate the 'oppressed', thus avoiding them from becoming politically active and threatening the privilege of those creating the markets.

#### **8.4.1.2 On the concept of equilibrium**

As in post-Keynesian analyses equilibrium is not accepted as an adequate description of reality. However this is not because it is an abstraction which is not always useful, but rather because it is seen to deny the need for progressive change in economic structures. There is a conflict of utopian visions. Marxian analysis interprets the notion of equilibrium as a false vision given so as to mask the injustice existing in competitive market institutions.

In addition to rejecting the idea of equilibrium Marxists point out the incoherence in the theory which results in the breakdown in market, as mentioned above. Marxists however aim to promote the breakdown, for example non-acquiescence to the payment of environment taxes and attempts to gain consent in providing compensation for development. They hope that the resulting conflict will help overcome 'false consciousness' and promote political pressure to change the competitive market institution.

#### **8.4.1.3 On uncertainty**

The externality of information is avoided in classical and neo-classical economics by reliance on pricing. Thus technical knowledge exists only as a commodity within a market; the commodity of a service. Professional service is interpreted in this way also, including that of a professional engineer. Thus the idealisation of information by engineers can be given a Marxian interpretation as being due to the desire to mask their ignorance and inability to provide the service they are selling. That uncertainty is not fully incorporated into engineering methodology (including in engineering economic analyses) can be interpreted as occurring because it would interfere in the competitive bidding process between engineering consultants and engineers in governing authorities. Marxian analysis interprets the situation as one where selling a service and the privileges gained from being the expert is considered by engineers to be more important than the technical truth and social responsibility.

#### **8.4.1.4 On the neutrality of money.**

As in post-Keynesian analyses it is an assumption that is rejected because money as an entity has a real effect other than to represent utilities and to increase ease of distribution of production. Financial institutions creating and controlling money are seen as having an agency in economic interactions. However Marxian analysis adds that the notion of the neutrality of money is an ideology of classical economics so as to mask the effect the financial institutions controlled by the capitalist class have on society as a whole.

#### **8.4.2 Neo-Marxism**

Neo-marxian analyses do not see consciousness as totally dependent on economic activities. The critical social science tradition is the main expression of this variant of Marxism (see Chapter 4). There is concern and interest for the individual in their process of overcoming their alienation and false consciousness within structural power relations. Education, other than politicization for rebellion, is seen as a viable means to help in this (e.g Friere 1972). Change is seen as able to come from consciousness and not only from change of economic structures. The aim is to create conditions allowing rational discourse so as encourage the overcoming of false consciousness through talking about the issues. A step towards reconstruction after the completion of deconstruction is therefore made, without it being left to utopian processes.

However the overcoming of false consciousness is still seen in the adversarial situation of the oppressed and oppressor. The need for reflexive reconstruction of collective worldviews creating the structural power are not explicitly considered, and so neither is the adequacy of theory to help overcome alienation from relatedness (see Chapter 3). Even though methodological individualism is rejected, the Enlightenment individual is still accepted. Spiritual concerns with the existential search for meaning and relatedness are not addressed, except perhaps in an implicit way by some neo-Marxist psychologists (e.g Fromm 1942). Alienation is considered only in the sense of alienation from society through economic processes which allow objectification of other people as instruments to help in the creation of profit. It is not appreciated in terms of 'eternal recurrence' (see Chapter 4).

#### **8.4.3 Conclusion**

Marxian and neo-Marxian economic analysis has value in pointing out the incoherence in classical and neo-classical theories, i.e. it is helpful in deconstruction. However as a normative theory for reconstruction it appears to be based on a philosophy

which does not adequately take into account the externality of the psychological and metaphysical reality. As a consequence the interpretations and recommended actions made are problematic.

## **8.5 POSTMODERN THEORIES**

Postmodern economic theories arise from four main sources: post-structuralist analyses making a critique of Marxism, anthropological analyses of non-western cultures, feminist and the 'small is beautiful' type of economics embracing alternative cultures (e.g. Schumacher 1971). They have features in common.

### **8.5.1 Post-structuralist theories.**

Jean Baudrillard was an initiator of these economic theories (see Kellner 1989 for a good review of Baudrillard's work to that stage). A fundamental feature of Baudrillard's view is the importance of signs or images in economic relations. He integrated them into an analysis similar to Marxian analysis of commodification. They are perceived as being held by people so as to indicate their place in society in the process of seeking social integration and privilege. Status is indicated by consumption. It is argued that they are required because a worldview is held that sees reality objectively where values are able to be fully represented by utilities able to be given monetary representation. His argument is that signs are the means to support a social differentiation by instituting a system where status symbols are bought. So what is termed 'commodity fetish' in Marxian analyses is reinterpreted as a 'sign fetish' and due to alienation and nihilism giving a neurotic quest for social integration rather than ontological growth (see Chapter 3). Postmodern social life is seen as dominated by a concern about social standing gained by image (sign). The signs present in commodities act as a language game ordering society which produce the alienation and nihilism. As a language game of structural power, signs interact to form a system. Postman (1992) links the images used in this system to technology because it is through them that they are constructed. Such a view accords with the post-Marxian analysis of Ellul (1980) which interprets modern technology as a system alienating people (see Chapters 3 and 4).

The difference between post-structuralist and Marxian analyses is that in post-structuralism the signs (commodities) are seen as being created by people, whereas in Marxism they are an expression of a deterministic economic process. Post-structuralism rejects the deterministic aspect of Hegelian philosophy that Marxian analyses are based upon. Hegelian philosophy is held only to the extent that no analysis is ever perceived as



perfect; i.e incoherence in understanding and hence theories and unreflected upon actions (worldviews) is seen as inherent as a type of irony (McGowan 1991 and Chapter 4).

As mentioned in Chapter 4 this irony is related to a further one relating to alienation. It refers to the inherent unrelatedness that people have to varying degrees due to lack of ontological growth. Systemic reflexivity of 'eternal recurrence' produces a Cosmic irony.

Hence human agency and human existence is seen at the centre of economic activity. Incoherence is seen as occurring but it is seen as an inherent condition. Ignorance is seen as an expression of the alienation from relatedness being expressed in image making and negative freedom (see Chapters 3 and 4).

Thus postmodern commentaries are not narratives about the oppressed versus the oppressed as in Marxism, but rather elucidation of types of collective neuroses. Virulent criticism is made of the degraded human existence in modern economies (e.g Pfohl 1990). Classical economic theory is not interpreted as masking oppressor privilege, but rather as intellectual 'idols' (symbols of immortality) held in the attempt to avert facing a reality which is psychologically difficult for people living in despair and alienation. The alienation is seen to occur for 'oppressors' as well as 'oppressed' though arguably harder for the 'oppressors' in keeping with the view of religious traditions.

Methodological individualism is seen as maintaining sign fetish to a level where there is extreme alienation, both through and expressed by the proliferation of signs. Postman argues that the technological system is an 'information glut' which has disoriented people so much that they have a very incoherent view of reality. Distraction has become institutionalized as consumption. This disorientation allows sign fetish and the icons of technology to order society (Postman 1992).

The disorientation resulting in sign fetish is interpreted as allowing normative ideals of greater consumption hence productivity, growth and efficiency to legitimate the differentiation and ordering of society which results. This is so much the case that everything is seen to be being brought into the orbit of commodification. The consequence is a deepening loss of self-transcendence or reflexive process, and hence a loss of creativity and self-determination. Instead of seeking self-transcendence through a use of positive and moral freedom, people have a 'magical' belief that more consumption will make them happy (Kellner 1989). Consumption is not tied to needs or pleasure as classical theory held/holds it to be. Rather it is tied to symbols of social standing, i.e. sign fetish. People have become unable to be aware of their real happiness as well as real needs because of their alienation.

Implicit in the post-structuralist analyses is the view that overcoming alienation will allow real needs and what brings fulfilment to be (re)discovered. However post-structuralist theories to date have merely been an expression and are part of the deconstructive stage of postmodernism because they have not fully questioned the Enlightenment individual (McGowan 1991). So the spiritual reality giving rise to relatedness is not considered. It remains an unconsidered externality. However other postmodernists do so as explored in Chapters 3 and 4.

Post-structuralist theories are critical analyses that describe the economic reality as it presently is socially constructed, and point out that change can come through human creativity if they (we) choose. Post-structuralist theories however are not in a position to offer a coherent reconstruction.

### **8.5.2 Anthropological theories.**

Various economic processes have been elucidated by anthropologists that are not able to be described as mechanisms or political processes. In effect further externalities are explored.

Kellner (1989) has also argued that much economic activity is not adequately described by either Marxian or classical/neo-classical analyses. He points to the work done by anthropologists on the importance of gifting, and the offering of sacrifices carried out to maintain relationships and access to resources.

#### **8.5.2.1 Gifting.**

Kellner has reviewed that there is an 'aristocratic' approach where there is gifting of surplus as a way to maintain domination. Another term for it may be 'patronising' economic activity. Far from it being only an activity of anthropological importance it is a very common strategy in the 'development' process. It has played a very important role in the economic development of floodplains in Aotearoa/New Zealand (see Chapter 10).

Another type of gifting is gift exchange. It is an expression of reciprocity and as mentioned above is according to Habermas (1971) at the core of the meaning of a market as a viable system. O'Connor, M (1988) links it to concepts in traditional Maori culture (see Chapter 3 also).

#### **8.5.2.2 Sacrificing**

Sacrificing to the environment is observed as being carried out to try to placate the indeterminate activities and to maintain a resource supply. This is an attempt to make a

relationship with the beings in Nature that are required to be interacted with so as to obtain resources. The important thing to recognise here is that uncertainty is being recognised and a strategy is embarked on to cope with it: i.e by trying to relate to the non-human world so as to gain a cooperative economic relationship. There is an explicit recognition that there are not always technical or even social organisational solutions to economic interactions. The externality associated with ecological integrity is explicitly faced (see Chapter 4).

### **8.5.3 'Small is Beautiful' theories.**

Schumacher (1973) has been very influential in promoting consideration of economic systems other than Western theories based on the worldview of the 'Enlightenment'. As an example he discussed Buddhist economics, pointing out however that he could have equally used Christian or other religious views to do so. The point he tried to make was that it is possible to have an economic theory which respects intrinsic values, i.e. a hermeneutic of respect can be used (see Chapter 4). In doing so he included the externality of spirituality and the externality of information concerned with it. The significance of this is that it gives a basis with which to reconstruct economic interactions that attempt to overcome alienation (see Chapter 3 and 4).

Many postmodern commentators refer to different religious traditions including Western traditions as sources for possible coherent worldviews (see Chapters 3 and 4). Also there are professional concerns for responsibility which make serious engineering groups make stands for alternative economic worldviews, e.g. Engineers for Social Responsibility (Blakely 1994, Morrison 1994 and Morrison 1995c).

There are postmodern commentators arguing that the recovery of Western heritage and views from other cultures can serve to provide a basis for new worldviews which can produce the needed creative change required in the face of present social incoherence. Examples of these from engineering literature include Davies (1993) and Morrison (1993).

### **8.5.4 Feminist economics.**

Feminism covers many intellectual traditions. However, as Strober (1994) points out, when applied to economics there is a common thread in having a concern about the economic standing of women. So a common perspective is that economic processes can be unjust and there is a need to correct this. Interpretations follow neo-Marxian and post-structuralist lines while emphasizing the need to consider externalities that are the context within which economic activity is carried out (e.g. King 1989).

A specific feature is the assertion that some activities traditionally linked to male activities (i.e. hunting and war) serve as the archetypes for normative Enlightenment theories of economic activity. - At the centre of this criticism is the objectification of Nature enshrined in the Enlightenment which emphasizes exploitative activity and efficient utilisation in scarcity. Traditional feminine activities (specifically agriculture) are more concerned with reaping from what Nature provides in abundance, and so in reflection plenitude and grace are seen as more appropriate to place at the centre of economic theory. A hermeneutic of respect is upheld - respect for all beings in Nature (see Chapter 4).

## **8.6 ECOLOGICAL ECONOMICS**

Ecological economics covers many economic intellectual traditions. As such it cannot be placed as a postmodern theory even though there are postmodern economists who see themselves as working within ecological economics. The common concern that however defines ecological economics is the attempt to take the externality of ecological interactions by human society into account in economic theory. Ecological integration is seen as important. Traditions involved range from neo-classical concern for environmental taxation (environmental economics) to application of anthropological studies of alternative possible economic interactions (postmodern economics).

What is perhaps missing is a concern to seek coherence, and to overcome incoherence, so that practical improvement can be sought and achieved. As a suggestion on how this can be achieved, a reconstruction of economic theory is given in the next section. It is arguably an example of ecological economics as well as postmodern economics.

## **8.7 A POSTMODERN ECONOMICS OF RECIPROCITY**

An aim of a reconstruction of economic theory must be to appropriately include all externalities which must focus on the need for integration personally, socially and ecologically. Also it should seek to gain a coherent approach. A coherent view can serve as the basis for a normative theory which can remain open to second-order feedback.

The review of economic theories in previous sections has indicated varying degrees of ignorance as to what externalities need to be taken into account. However naive relativism is going to be avoided here so as to not fall into the same trap. It is recognised instead that the question as to what externalities are, will always remain an open question as new issues may always be raised. However what can be done is to attempt to adequately take into account those that are experience of second-order feedback and so a contingently appropriate functional reconstruction can be carried out.

### **8.7.1 Externalities.**

The externalities that have been found to be needed to be taken into account through the above review are:

- (a) Functional roles within society.
- (b) Functional roles in ecology that human societies' interactions perform with their environment.
- (c) Structural power relationships that exist due to collective worldviews.
- (d) Psychological and spiritual bases from which the existential dimension in human views, decisions and actions arise.
- (e) Information about the above (a-d).

### **8.7.2 Seeking coherence through integrating externalities.**

The task of becoming aware of what externalities have to be taken into account is also the process of seeking coherence. This is helped by focusing on the incoherences pointed out by Marxian analyses, though the adversarial component and the political agenda are best ignored. Reflexive consideration is also helpful as the most difficult incoherence to see can be that which oneself is participating in, i.e. one's own false consciousness or neuroses.

However it is necessary to remember that even though coherent theories may be able to be achieved through serious reflection and reflexivity, some people also have 'theories in use' which they apply so as to socially integrate, while remaining aware of the incoherence of their actions (see Chapter 4). This can be expected to apply to the application of economic theory as well. Therefore one of the aims is to encourage those using economic analysis to develop coherent 'theories-in-use' as well as a vision of the ideal situation. Therefore the emphasis is on reconstruction that is practical to operationalize.

#### **8.7.2.1 Overcoming methodological individualism.**

The difficulties with methodological individualism outlined in previous sections can be interpreted by considering the distinction between two interrelated fields of analysis outlined in Chapters 3 and 4. The processes which individuals engage in to seek personal growth (field 1) are different to those which groups of humans engage in socially and ecologically (field 2). There cannot be ontological growth nor coherent system construction unless both are recognized as well as their relationship appreciated. It is argued here that non-awareness of this and/or confusion of them has led to most of the

incoherence in economic theories since the Enlightenment. The individual has been considered separate from the environment and used as a means for social goals.

Problems only occur when one or the other is devalued and one field attempts to claim total knowledge. For example pre-Enlightenment Europe used existential knowledge concerned with spiritual reality sometimes where scientific analysis may have been more appropriate. However since the 'Enlightenment' the opposite has occurred and hence the resulting economic theories express this fault.

The consequence is that economic theories attempt to essentialize human nature, denying the existential field of ontological growth involving natural freedom and potential for moral freedom. Humans do not have an essential nature, but self-construct their nature through their creativity and growth in the exploring of their reality on their journey in search for meaning and purpose for their activities (see Chapter 3).

That many/most people do not engage in self-construction, and prefer to merely socially integrate and accept the human nature (bounded rationality) they are expected to have in the existing structural power relations, is why essentializing can appear a plausible type of social theory. But it is the consequence of alienating language games. Alternatives can occur.

A danger Fromm (1942) pointed out is that when the existential field of the individual self-construction is denied, it is conflated with the group field, and meaning for existence is given in terms of the group process. As mentioned in Chapter 4 it is the fundamental flaw in fascism. It arises in other institutions as well. For example classical and neo-classical economics essentializes human nature in the model of 'rational economic man'. This model does not refer to the state of individuals' existences but rather to the social role performed by a person in a competitive market institution. The existential need to seek meaning is held to be achieved when people are successful in the competition to become wealthy. Hence the post-structuralist analysis of the resulting society leaves people only able to find meaning in the attempt to achieve an image placing them in a social hierarchy. The success of the image comes from the degree of consumption represented by the image (i.e. wealth).

A consequence of classical economic essentialization is that an important concept referring to individuals in field 1, that of growth, is applied to field 2 instead. Defining growth collectively as group production and consumption (wealth creation) is problematic in the attempt to achieve what is sought to be achieved in field 2. Also growth is misinterpreted at the individual level to mean seeking to produce and gain wealth as described above.

Another example is Marxian analysis of human consciousness as the consequence of economic structures. Here human existence is essentialized as the product of economic interactions. What Marxian analyses may in reality be pointing out is the interaction between groups within structural power relations. The existential need for meaning is held however to be given in being a political activist creating conflict and through that change in economic structures. Once again it is projected onto field 2.

Both of the above examples are expressions of the general case of a person seeking to gain existential meaning through the role they perform in field 2, thus making the means an end. As mentioned in Chapter 3 this can apply to professional roles as well and leaves a person a mere functionary and not creatively involved in expressing their role so as to achieve the end it has. Those who use Enlightenment economics of any tradition can easily fall into this because such economic theory obscures field 1 through the essentialization conflating the two fields.

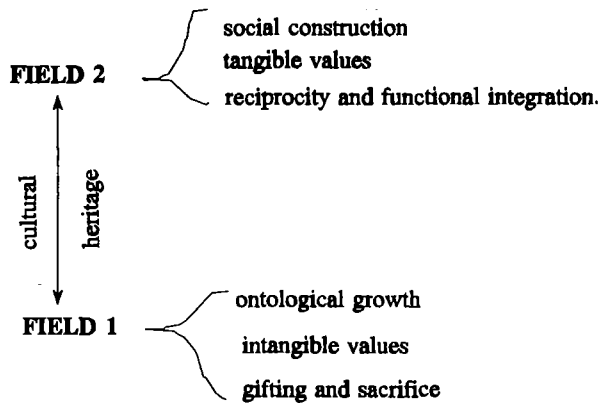
However if the distinction between fields is recognised then economic analysis of field 2 can be carried out for collective activities expressed in social institutions and ecological interactions between populations in a coherent way, with economic analysis associated with field 1 analyzed differently. Recognising the distinction between fields enables externalities (a) and (b) to be taken into account and integrated together thus defining the appropriate role for economic institutions. Once this is defined (necessarily naturalistically) an economic theory can be defined which is an appropriate one to be implemented as a management/planning or policy tool.

#### **8.7.2.1.1 Interaction of fields.**

Field 2 does not concern itself with intrinsic values but rather utility values as institutions are means to help nurture the intrinsic values of the individuals that belong to the group (of the institution), as well as others in other groups that the group functionally or in reciprocity interacts with. See Figure 8.1 for an outline of the characteristics of the two fields as they refer to economic issues.

##### **8.7.2.1.1.1 Field 1.**

Because institutions described in field 2 are a means to help nurture the intrinsic values of individuals in field 1, what field 2 should be is determined by what field 1 is. But field 1 is not anything. Rather it is an existential potential. What is in field 1 is self-constructed and so what is needed in field 2 are institutions that help nurture ontological growth of individuals on their journey of self-construction which explicitly



**Figure 8.1;** Characteristics of the two fields.

relates field 2 (world) to field 1 (self) (see Chapters 3 and 4). As outlined already the dimensions of growth are reflected by interbeing between mortals and gods that self-construction explores in the attempt to seek meaning and purpose for activities (externality (d)). Mortals' integration into the immortal life of the gods defines ontological growth and defines how knowledge needs to be systematically constructed to create sphere 2. At best the institutions described by field 2 should be integrated into the immortal gods of human community and ecosystems.

Arguments from Chapters 3 and 4 suggest that the process of ontological growth through self-construction opens to the 'ground of Being', sacredness or grace that is eternal and involves expression of caring or loving through giving to and sacrificing for other individuals (non-human as well as human). Thus the economics of field 1 is potentially that of giving, with sacrifice being expressed when needed. Eventually however all is sacrifice whether it is chosen or not because biological death gives life to other individuals. This view of gifting and sacrifice extends that expressed in postmodern economic thought to date.



#### 8.7.2.1.1.2 Field 2.

The challenge is to consider how to create field 2 so that it institutionalizes gifting and sacrifice, and hence so that the ontological growth of individuals in field 1 is nurtured.

The concept of reciprocity is an appropriate principle to base the (re)construction of institutions on so as to achieve this, because it models a systemic process of integration which can be with the immortal gods of community and ecosystems. Both cooperative markets and economically supported functional roles of service to the community fulfil this for human community through mutualism and symbiosis by human populations (cultures) with non-human populations achieving ecological integration.

Such integration enables stable interactions, thus providing stable environments for individuals' economic requirements to be fulfilled, hence their full growth through full expression of potential giving from development of skills. Note however that, as mentioned above, this cannot be achieved merely through functional role-playing as an end in itself. It also requires appreciation of the purpose for the role, and critical and creative adaptation of it to fully express its purpose if required. In the attempt to gain coherence the conscious distinction between the two fields is required to be made for it to be expressed meaningfully. The role can then be performed meaningfully as long as there is the integrity to implement it rather than merely acting out a default theory-in-use of an inappropriate language game.

Therefore the economic aim of a society should be to develop institutions which enable the services required of a particular society to be fully expressed, with reciprocity occurring to justly provide for all, thus ensuring that the services are maintained as well as the growth of all individuals being nurtured.

Three types of society can be characterised from this perspective. They form a continuum.

1. Societies can be very small and so characterised as 'subsistence' with reciprocity occurring in functional differentiation of roles within society. Mutualistic and symbiotic relations between the society and their ecosystem occur. Giving (and receiving) occurs within the group and with their environment.
2. If a society or group is only to varying degrees in a 'subsistence' relationship with their environment then they engage in reciprocity with other societies as well as within their ecosystem. This can be by gift exchange or by a cooperative market.
3. The other extreme is a society composed of professional groups (producers as well as service suppliers) who collectively form a whole of interacting functional roles. The different groups are wholly dependent on reciprocity between groups within the society to

support them in their service to society, as well as cooperative markets that distribute production within the society and between societies.

The societies that Western countries have is characterised by type 3, but with latent and emergent forms of type 2 in traditional indigenous cultures and alternative Western cultures. For example in Aotearoa/New Zealand there is Traditional Maori culture and Permaculture.

#### **8.7.2.1.2 Art and science.**

Individuals' experience of their growth in giving and caring (love) so as to find meaning in their existence in a harmony with other beings (non-human and human) is expressed in art which takes on a collective significance, in the attempt to describe their journey and lead the way. It forms what can be called cultural heritage. It can be related to the natural environment in narratives as well as expressed in constructed art objects. These give rise to intangible values. Tangible values are what science is concerned with.

One of the expressions of giving by individuals which has existential significance and meaning is that of economists and managers, planners and policy makers who try to create social institutions which provide for the economic requirements for the growth and fulfilment of all individuals. These are tangible values. Science is used to do this. Thus economics is a science when it has this as a goal. In the attempt to essentialize economic activities rather than reconstruct them, economics remains non-science because it lacks an empirical basis for its analysis (Eichner 1983). What is required is an adequate empirical analysis of required functional interactions and metabolic requirements to base reconstruction upon. This is theoretically possible only if it involves the incorporation of externalities.

Note that the theory developed here is coherent in terms of how the values of the economist are not contradicting those of individuals they are modelling. All are modelled as naturally free and capable of moral acts.

The post-structuralist view of inherent irony is important to recall at this stage as no social construction involving scientific abstraction to structure it can be expected to be perfect. No institution is perfect, and can be expected to get less so as co-evolution proceeds. There is the need to recognize unknowing that occurs existentially and politically in sphere 3 and to be open to second-order feedback (see Chapters 3 and 4).

Therefore continual reflexive reconsideration of what are currently defined as appropriate institutions is necessary so as to be receptive to dissatisfaction or injustice that

may occur as well as monitoring for degradation in the environment. This allows for and requires consensus-seeking about what systems are working, as well as encouraging individuals to seek to gain coherent understanding (theories and visions) themselves (see Chapter 3). Appropriate forums that encourage this are important, i.e. institutions whose role is to nurture the individual growth process of being able to reflexively consider incoherence so as to seek coherence. Such institutions are a form of cultural heritage as they involve the field of understanding covered by art. It is expressed by rituals and ceremonies. Art makes the void of unknowing present and less threatening. Thus both art and science are needed and require to be synthesized.

#### **8.7.2.1.3 Process of improvement.**

As outlined in Chapter 4, the process of improvement is instigated by individuals' creativity changing the language game of the society. The aim is to help make the language game more coherent and consensually based, i.e. to overcome ignorance expressing structural power relations which are not adequate.

The language game is able to be partly reconstructed by the use of scientific analysis as outlined above. To see the potential for growth in individuals (i.e. sacredness) gives the direction for producing it. Reconstruction of institutions to provide economically for the ontological growth of individuals and all interbeing is one expression of this. The consequence is that one of the main negative consequences of the Enlightenment is overcome. The objectification of people through the expression of negative freedom to compete in market institutions is no longer modelled.

Some individuals gift surplus and or sacrifice (opportunity cost) so as to help supply the economic requirements for others when imbalance within reciprocity occurs, which can always be expected to occur to some extent. This can occur collectively in institutions, e.g. service groups and NGOs, or by economic entities in field 2, e.g. a farm business. They gift and sacrifice for non-humans as well as humans. Examples of what is done are the voluntary non-utilization or gifting to be a reserve of indigenous forest, or non-disturbance of wahi tapu and other cultural heritage. This approach is not dissimilar to the Marxian existential type of political activism except that the type described here is not adversarial. Rather they do what they can to help individuals (human and non-human) who need help (economic and culturally). They recognize the difference between the two fields whereas the Marxian political activist does not and can proceed to do violence against individuals (economically and culturally).

The other occurrence is that of groups either serving in reciprocity or sacrificing

(more often than not sacrificing) to construct cultural heritage so as to direct the process of growth and the process of seeking coherence. They are the artists of society. Externality (c) and that part of (e) associated is involved. This occurrence needs to be nurtured as it overcomes one of the other main negative consequences of the Enlightenment that have been problematic: the objectification of Nature leading to alienation of humanity from the rest of Nature.

#### **8.7.2.1.4 Avoiding idealization.**

It is necessary to avoid idealization that posits human nature as essentially good as well as the essentialization according to 'economic man' axioms that it is bad. Both conflate the two fields. An example is essentializing the process of reciprocity in analysis of indigenous peoples' economies as if the individuals in them do. A consequence is that such cultures are not perceived as having individuals within the process of self-construction that all humans do, and that such cultures are not recognized as being socially constructed and inherently imperfect within a process of co-evolution with their environment. This draws attention away from what could be actually learnt from such cultures which have contingently but relatively better institutionalized second-order feedback.

What is necessary to successfully implement postmodern approaches is to recognise freedom and creativity of all humans and to nurture the possibility of moral freedom through respecting the intrinsic values present. If all intrinsic values are institutionally respected then abuse will not be tolerated and so guidance of individuals is carried out and justice maintained. To obscure the role of cultures by romanticising them appears to be ideological and a patronizing response by Western culture.

#### **8.7.2.1.5 Conclusion**

The liberal tradition of respecting individual freedom and choice at the basis of methodological individualism is upheld and extended. It is extended by recognizing that there are externalities pertaining to individual growth, and that there are institutional requirements to nurture this by maintaining justice so that all (human and non-human) are nurtured. It is argued that the incoherence of existing methodological individualism can be overcome through recognizing explicitly the distinction of the two fields of the individual and the collective in economic analysis.

### 8.7.2.2 Reconstruction of equilibrium.

As was pointed out in previous sections, equilibrium as a concept is best considered an abstraction. As such it can have a role in the (re)construction of economic institutions. This is because the process of co-evolution involves punctuated equilibrium. For periods of relative stability occur in the functional roles able to be abstracted in ecosystems between populations, including humans, with reciprocity allowing all metabolic requirements to be maintained. Cultural mutations are not selected for because they are not improvements. Such a process is an expression of sustainability and biodiversity and an appropriate goal to have in reconstruction of economic processes. It is necessary however to not essentialize the reconstructed equilibrium so as to maintain the adaptive process for further change to occur as it is required. Creativity and questioning must not be suppressed, nor monitoring abandoned even though they may not be pertinent at any particular time.

The process of reconstruction itself is an example of co-evolution in between states of relative equilibrium. Human populations adhering to Western culture are in a period of punctuated equilibrium and rapid evolution. Having the aim of an equilibrium can guide the process of co-evolution being carried out within these populations so as to reach balance, stability and sustainability and to enhance biodiversity. However it is a concept of equilibrium very different to that held by neo-classical economic theory.

Thus aspects of both classical and Marxian economic theories are adopted, but de-essentialized and externalities to both economic theories are included. The notion of equilibrium of neo-classical theory is maintained however but inverted. In classical theory equilibrium is the consequence of an unknown phenomenon ('invisible hand') operating to produce the best results through the collective working of a competitive market where the activities of individuals are known. In the approach developed here, the collective action is explicitly created through knowledge of and use of externalities so as to nurture the possibility of integration at the three levels of interbeing of the individual, human community and ecosystem. The phenomenon that produces the possibility of equilibrium operates through the holistic operation of sacredness or grace that inspires moral freedom to be enacted by individuals in their discovery of community through establishment of the ethical relation (see Chapters 3 and 4). The natural (or 'supernatural') holistic principle is considered to operate in the existential field of spirituality rather than in the collective field of an 'invisible hand'.

In Marxian analysis evolution is considered to proceed through conflict to produce an eventual equilibrium. Marxian analysis does not however consider the externalities of

ecology nor existential self-construction in this process. Thus the holistic principle discovered in field 1 through self-construction is not recognized here either. Equilibrium is considered to be the deterministic outcome of the collective process of conflict. However the dialectic of conflict within the reflexive spheres is part of the process of co-evolution and is particularly pronounced in periods of the punctuation of equilibrium. As it is occurring now in Western societies, it is important to take cognisance of it.

Both classical/neo-classical and Marxian essentialization in field 2 result in the ecological and social dynamics involved in ecological sustainability and social stability not being taken notice of. Therefore even though the notion of equilibrium is involved in those theories, the implementation is inconsistent with it occurring. This is most clear in the way growth is considered.

As mentioned previously, growth is an occurrence of individuals in field 1. It only occurs in field 2 as an abstraction used metaphorically as an analogy. It applies only to mortals. Growth is linked to the holistic principle of spirituality and so is central to the process of achieving equilibrium. Growth is nurtured if equilibrium is held as a goal and equilibrium occurs if most individuals are able to and do fulfil their growth potential of learning to care. However if the abstract entities in field 2 are what are defined as growing then equilibrium is contradicted. Both neo-classical and Marxian theories rely on supposed natural (or supernatural) processes to produce equilibrium out of such a collective growth rather than responsible and creative use of scientific information and understanding of processes.

Neither do Post-Keynesian analyses consider realistically the economic processes which occur in field 2. They are an improvement over neo-classical and Marxian analyses because understanding of processes is sought. But they still miss the point that equilibrium is an appropriate normative goal that should be sought to be socially constructed. An adequate theory of agency that distinguishes the two fields of action is missing in all Enlightenment theories and so an understanding of hierarchical integration is not grasped. However analyses of existing economic processes are relevant in the consideration of how to implement reconstructions. See Section 8.7.2.4 for an example.

#### **8.7.2.2.1 Reconstructing public policy.**

In light of the need to create reconstructions that are able to be practically implemented so as to avoid the adoption of incoherent theories-in-use, consideration of straightforward operationalization is very important. Therefore this needs to be remembered when beginning to consider what is required for equilibrium and hence

stability, i.e. sustainability and biodiversity. In doing so, all of the externalities outlined previously need to be taken into account. In participation with the public, the information involving all externalities is used to define goals. These become how sustainability and biodiversity are defined normatively for the reconstruction process. In the terminology of neo-classical public policy tools (CBA), the goals define what the benefits are. The costs are the resources involved in implementation of management actions to achieve the goals. Thus the appropriate approach is to seek cost-effectiveness in achievement of goals rather than carrying out a CBA. Thus an explicit and rigorous multi-objective analysis is required.

A management option is viable and will successfully improve the situation if the costs involved in achieving the goals are acceptable. A possibly appropriate approach is to consider minimum cost as a goal among others (see Chapters 9 and 10). Then tradeoffs between achievement of the different goals by various management options can be considered according to further goals (meta-rules), themselves obtained through public interaction.

It is also developed in Chapters 9 and 10 how individual groups occurring in field 2 need to be considered separately, as well as analysis of an overall semi-closed system that is encompassed by a complete management plan. For each group (economic entity) some net income will be required in the type of societies being considered in floodplain management for Aotearoa/New Zealand. Overall this will have to be achieved for all such economic entities for the achievement of justice.

#### **8.7.2.2.2 Benefits and costs.**

Both benefits and costs in classical public policy analysis are categorized by two independent couples, thus giving a typology of four types. They are tangible and intangible; and direct and indirect. A table of the types of benefits and costs expected from a reconstruction are given in Figure 8.2. The direct tangible benefit of increased production will produce a surplus able to be given as rates or tax to help pay for the management actions and hence direct tangible cost. What is an acceptable income for the producer over and above this is related to the reciprocity involved in exchange of goods and services. It is also a political issue. Some rules have to be obtained through public interaction to proceed to plan an appropriate management plan.

Some indirect tangible benefits enable increased direct tangible costs to be maintained because direct tangible benefit through increase in production can result. For example increased access to resources. Similarly intangible benefits may also. For

<b>BENEFITS</b>			
<b>INTANGIBLE</b>	(field 1) ontological growth	(between fields 1 and 2) increased cultural heritage	
	(field 2) increased production	(field 2) increased acces to resources and implemen- tation of services	
<b>TANGIBLE</b>			
	<b>DIRECT</b>	<b>INDIRECT</b>	

<b>COSTS</b>			
<b>INTANGIBLE</b>	personal trauma	destruction of cultural heritage	
	cost of management options	interruption of access to resources and implementation of services	
<b>TANGIBLE</b>			
	<b>DIRECT</b>	<b>INDIRECT</b>	

**Figure 8.2;** Benefits and Costs matrix.

example increased tourist operations. Therefore even though goals associated with some benefits are not directed to fulfil ability to handle increased costs, this may occur. However this cannot be the purpose for the goals. If it is then conflation of the two fields is being carried out and the overall aim of equilibrium is less likely to be achieved. Note that this conclusion is in direct contrast to the view held by the classical tradition.

Direct costs are associated with the implementation of management options which enable stable production to be maintained. This applies to intangible costs as well because cooperation between individuals is a requirement.

Indirect costs (tangible and intangible) are taken into account in the direct cost associated with implementation of management actions which restrict indirect benefits to acceptable levels.

Direct and indirect cost are not necessarily independent. Some possible management actions that become part of cost-effective management options can do both. This has to be taken into account when analysing management options for cost-effectiveness.



### **8.7.2.2.3 Conclusion**

If there are cost-effective management options which achieve the goals; i.e. if surplus occurs such that reciprocity can be implemented for the whole social system providing for metabolic, service and cultural requirements, then an equilibrium can be aimed to be achieved with the human occupation of the floodplain close to how it is at the time of analysis. If such management options are not feasible then some major adaptation is required by the human population in its colonisation of that particular ecosystem.

### **8.7.2.3 Realistic handling of uncertainty.**

Realistic handling of uncertainty involves the explicit representation of how well a defined economic goal is achieved. The mathematics developed in Chapter 5 can do this. The imprecision and uncertainty of acceptable goals and results needs to be known. To determine the uncertainty and imprecision of expected consequences involves information (externality (e)). The previous chapters on risk and hydrology outline what information is required for the physical aspects of floodplain management. Other specialized information is also required, e.g ecological information.

#### **8.7.2.3.1 Overcoming the technocratic presumption.**

As mentioned in Chapter 6 there are two general approaches to the question of uncertainty in achieving goals. Lack of information can either mean that the goal is presumed to be achieved or the opposite. As also already mentioned, the traditional approach of engineering methodology has been to presume that lack of information means that goals are able to be achieved because of the belief that if anything goes wrong then further technological work will be able to correct it. The same technocratic presumption occurs in the 'Enlightenment' economics tradition.

The technocratic presumption in the classical economics tradition occurs in two places:

- (a) essentialization
- (b) use of discounting.

Essentialization as previously mentioned, models system behaviour according to assumptions which are not realistic because the openness of existence in field 1 is not recognised. The further consequence is that when the system inevitably fails to work as planned, there is the attempt to enforce the modelled behaviour through the making of the Is-Ought fallacy rather than helping adaptation creatively through the creative input of individuals in the openness. The technocratic presumption is made in the belief that control of Nature, whether it is human nature or other Nature, will always enable such

goals to be achieved.

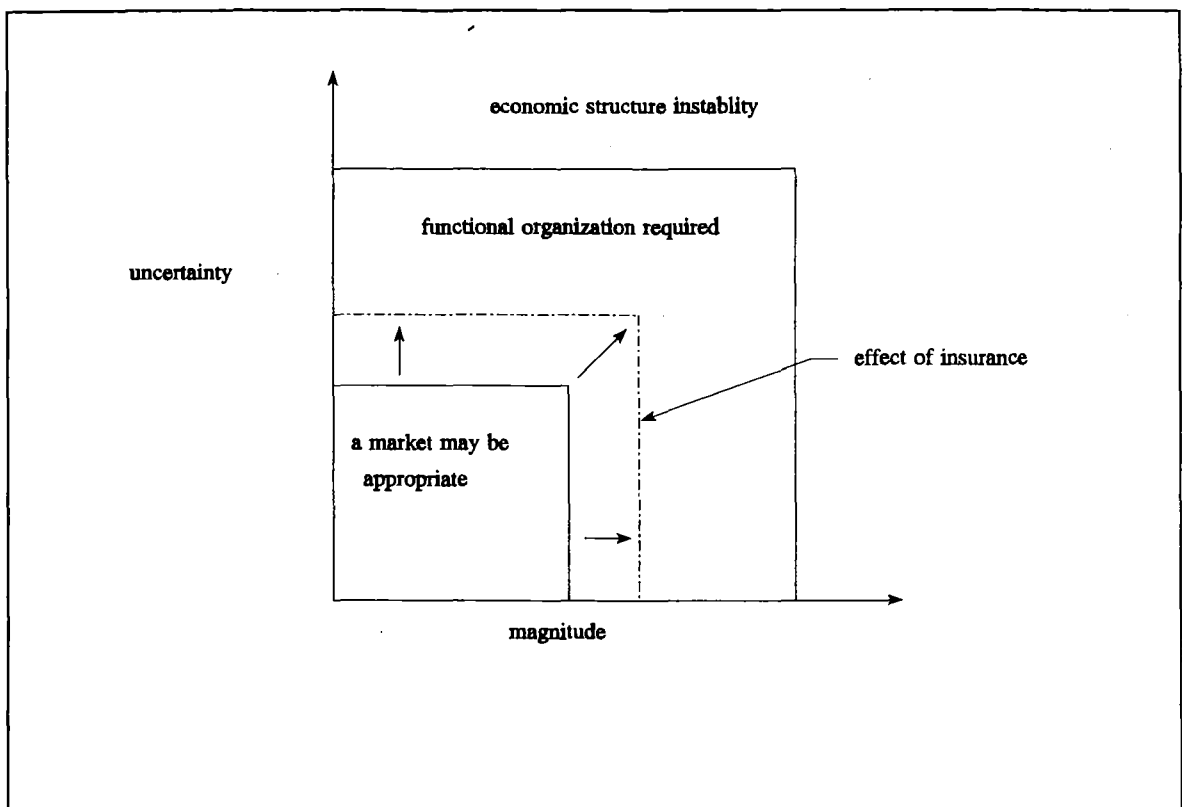
The use of discounting models increasing uncertainty as decreasing magnitude of events. It is used in the context of neo-classical analysis assuming that an equilibrium is reached through interactions in a competitive market. The externalities involved in the effects on society and ecology are not taken into account. The assumption is that the consequences of actions at the present become less important the further into the future that is considered. The presumption is the technocratic one that bad consequences will be able to be overcome if they arise.

To overcome the technocratic presumption it is necessary to model uncertainty in a way which makes the present policy-makers take responsibility for the consequences in the future of what is done now. To do this the externalities concerned with consequences have to be considered as well as possible. Then actions can be embarked upon to the extent there is information about whether or not the goals associated with seeking equilibrium will be achieved. Such an approach is fully realistic and respectful of science and its application in field 2. Further it encourages the development of scientific analysis so as to increase information thus enabling more efficient management actions to be made because less risk-averse decisions can be made.

When information is used in this way, uncertainty is analyzed rigorously and so technical analysis is not a marketable commodity. Such analysis of uncertainty stops the possibility of technical experts being pitted against each other in an adversarial way for economic gain that is quite rightly condemned by Marxian analysis.

#### **8.7.2.3.2 Markets and uncertainty.**

Akerlof (1970) has pointed out that a market is not able to exist if there is too great an uncertainty about pricing. This is applicable to floodplain occupation when there is uncertainty about the net income due to flood damage. However to the extent there is finance available to smooth out the effects of damage then the range in which a market is viable increases (see Figure 8.3). This effect is an example of the non-neutrality of money. An upper limit exists because single damage events can get too high for the stability of the system, no matter how much averaging out is possible. As outlined in Chapter 6 these events are 'catastrophes' and are a different type of risk. Rawlsian modelling of decision-making is appropriate here. Damage which refers to single catastrophic events interferes with the structure in place. Damage which is not able to be aggregated has intangible or indirect effects which makes the effects unable to be traded away through a market institution. Different goals refer to different types of values and



**Figure 8.3;** Economic structures typology.

so some damages/costs are not able to be handled by a market institution at all, e.g. those associated with cultural heritage, ecological reciprocity and social services. Risks associated with these have to be handled separately.

Damage which is able to be coped with by a market, as long as finance is available, is that which is able to be aggregated together. When damage is able to be added together it is able to be described as a utility and symbolised by money and exchanged accordingly.

Also the horizon for which the economic analysis is being considered affects what the uncertainty is. The period is likely to be the design period for the management plan being instituted. The shorter the period the greater the uncertainty, however the longer the period the greater the imprecision (see Section 8.8).

#### 8.7.2.4 Handling the non-neutrality of money.

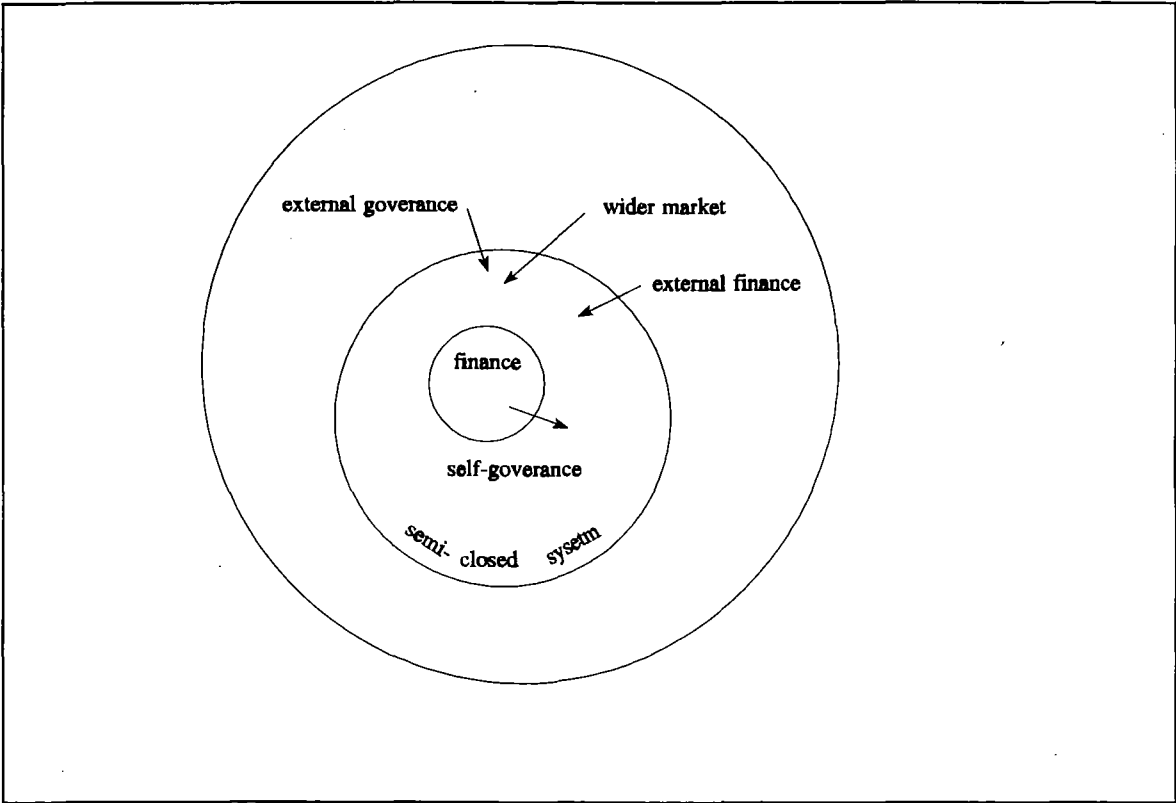
Incoherence occurs in the theory of the neutrality of money because it fails to recognise the effects financial institutions have. Failure to recognise the effects leads to an inability to realistically plan where a market institution is appropriate. A market institution is an appropriate institution to the extent money can be modelled as acting

neutrally.

The neutrality of money effectively models a situation where there is perfect insurance or finance. Such a model is only realistic under certain conditions. As mentioned in the previous section, it is when the uncertainty is not too high.

Even totally removing any suggestion that financial institutions have any bad will, it still has to be considered that they still however follow rules that can change and which can have real consequences on how economic entities can cope with uncertainty, e.g. change in interest rates or insurance premiums (see Section 8.8).

To take the consequences of financial institutions into account requires a realist analysis like that promoted by post-Keynesians. Figure 8.4 outlines the system to be



**Figure 8.4;** Semi-closed economic system.

analyzed. A reconstruction to handle non-neutrality of money as well other economic ‘mechanisms’ can only ever be considered to act over a definable system. Economic policy along these lines has to model a semi-closed system. The aim is to realistically know what can be reconstructed so as to achieve the goals promoting equilibrium and where a market is able to be instituted to help.

Financial institutions are creative and can be considered to be endogenous to the system. Because they are creative (can change their role), the system is self-referential

and so indeterminate. An analysis cannot determine what is going to happen because they cannot dominate the system. However some bounds or trends may be able to be defined, or better, some cooperation achieved between the groups.

As well as the indeterminacy due to the creativity in the semi-closed system, the effects of the market environment adds imprecision. Both of these have to be taken into account when considering where a market institution is appropriate. However when these issues are realistically faced the non-neutrality of money is handled. How to operationalize this for floodplain management is carried out in Section 8.8.

### **8.7.3 Conclusion**

A coherent theory has been suggested here that carries on in the tradition of liberal concern for freedom and choice. However major and fundamental changes have had to be made. The consequence has been to extend the perceived freedom and responsibility of individuals. A theory of reciprocity is operationalized by defining goals and analysis about how well different possible management options may achieve them. A realistic analysis of uncertainty and imprecision is required.

The goals can be formulated by rules. The next section develops how the goals can be formulated by rules and how the rules can form part of an Expert System for decision-making in floodplain management. It is continued in Chapters 9 and 10.

## **8.8 RULE-BASED ECONOMIC ANALYSES FOR FLOODPLAIN MANAGEMENT**

There are two aspects to the economic analyses that have to be taken into account.

- (a) Analysis of damage and viable management actions.
- (b) Analysis of the cost-effectiveness of management actions.

### **8.8.1 Analysis of damage and viable management actions.**

Three steps are outlined. They correspond to the process of taking externalities into account. The approach is to carry out an analysis making classical assumptions and using information realistically, pointing out the limitations on the assumptions outlined by criticism already reviewed and the affect on conclusions that can be made. From this an outline of what modifications are required is made, and a rule-based approach based on the postmodern theory of reciprocity explored in Section 8.7 is developed.

### 8.8.1.1 A classic equilibrium model.

Three assumptions need to be made.

(a) That externalities are not significant. This implies that the analysis of the use of floodbanks to mitigate damage in floodplain management is able to be analyzed independently of other issues and goals.

(b) That financial institutions exist which enable money to be treated as if it is neutral. The consequence of this is that a market is seen as a viable institution to order social choice.

(c) That economic entities have perfect knowledge about the available information. This is slightly different to the classical assumption of perfect rationality because here perfect knowledge means perfect awareness of the imprecision and uncertainty of the information rather than no uncertainty or imprecision. An implication of this assumption is that investors in determining their expected damage resulting from the implementation of a floodbank to a particular height have optimised the expected net benefit by choosing the particular investment that would do so.

#### 8.8.1.1.1 Economic optimization.

When economic analysis is carried out to determine the appropriate floodbank level to design for, an optimisation is carried out using cumulative stage/damage information,  $F_d(y)$ , and the cost function,  $f_c(y)$ , of a floodbank for protection up to stage  $y$ . These functions are derived for individual economic entities, and if more than one is involved then a utilitarian aggregation is used to give the cost function.

The direct cost can include expected maintenance from erosion over the design period  $T_d$  (see Section 7.7).  $F_d(y)$  is synthesised from the integration of the marginal distribution of damage as a function of stage,  $f_d(y)$ , and the pdf of the flood frequency curve,  $p(y)$ , as a function of stage in the range in which  $y$  is not exceeded.  $f_d(y)$  is the summation of individual damages if more than one economic entity is involved. What is of interest is the change in damage, i.e:

$$\begin{aligned}\Delta F_d(y) &= \int_y^{\infty} f_d(y) p(y) dy - \int_0^{\infty} f_d(y) p(y) dy \\ &= - \int_0^y f_d(y) p(y) dy \quad (8.2)\end{aligned}$$

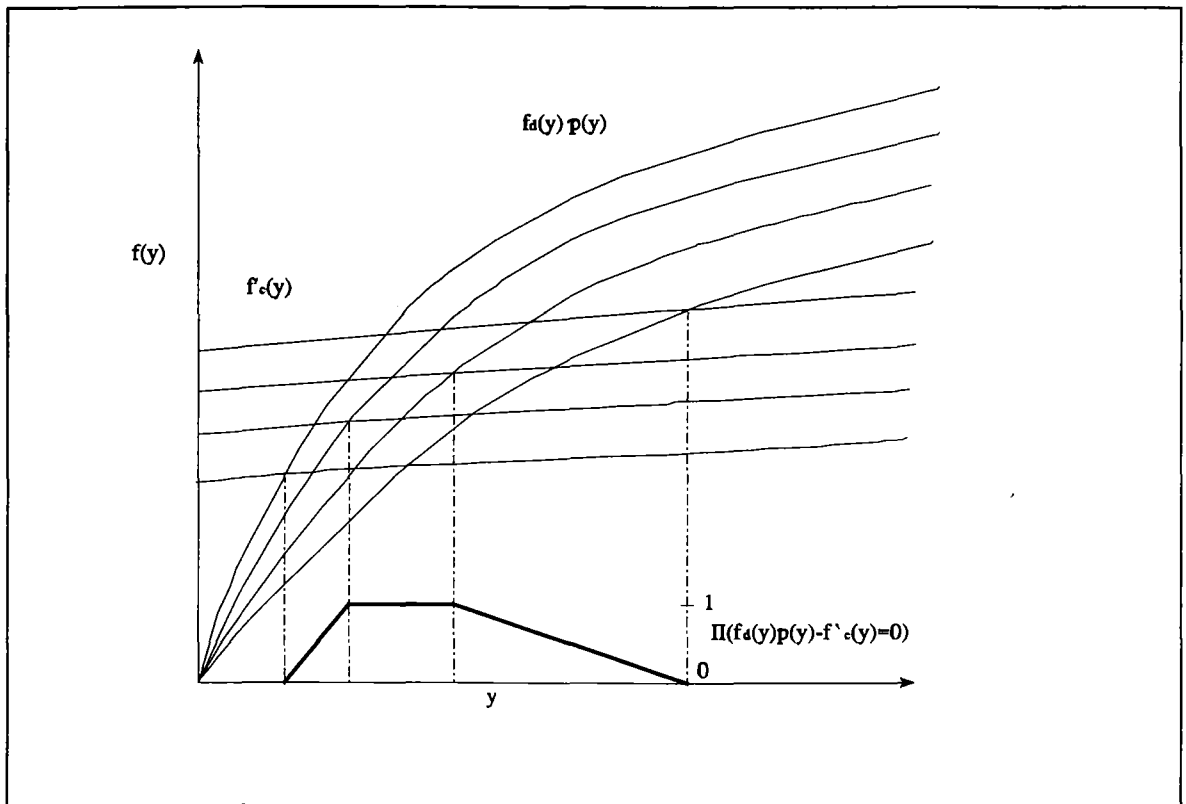
The optimisation to determine the most efficient investment in flood protection is given by:

$$dz/dy = 0, \text{ where } z(y) = -\Delta F_d(y) - f_c(y) \quad (8.3)$$

$$\Rightarrow \begin{aligned} -\Delta F'_d(y) &= f'_c(y) \\ &= f_d(y)p(y) \end{aligned} \quad (8.4)$$

However  $f'_c(y)$ ,  $f_d(y)$  and  $p(y)$  are fuzzy. It is necessary to compare the two sets of possibility functions given by  $\pi(f'_c(y))$  and  $\pi(f_d(y)p(y))$ . Discretization is needed to determine  $f'_c(y)$ :

$$f'_c(y) = \frac{\Delta f_c(y)}{\Delta y} \quad (8.5)$$



**Figure 8.5;** Optimum flood protection ( $y$ ).

Transformations are required to make Equation 8.5 isotonic (see Section 9.3.2) Figure 8.5 gives an illustration of the calculus of determining the fuzzy solution of Equation 8.4.

This can be carried out by making  $f'_c(y) - f_d(y)p(y)$  isotonic and solving it for when equalling 0 by using  $\alpha$ -level cuts. Alternatively it can be carried out by comparison of the resulting possibility functions through using Equations 5.18-21 which give indicators of possible and necessary inequality between possibility functions. Equality can be defined by when inequality is not significant, i.e:

$$\pi(f'_c(y)) \neq \pi(f_d(y)p(y)) \text{ and } \pi(f'_c(y)) \neq \pi(f_d(y)p(y)) \quad (8.6)$$

The support of the possibility function is given by:

$$\Pi(f_c(y) \succ [f_d(y)p(y)] \cdot) = 0 \cap \Pi([f_d(y)p(y)] \succ f_c(y) \cdot) \quad (8.7)$$

The core of the possibility function is given by:

$$\begin{aligned} \Pi(f_c(y) \succ [f_d(y)p(y)] \cdot) = 1 \cap \Pi([f_d(y)p(y)] \succ f_c(y) \cdot) = 1 \\ \equiv M(f_c(y) \succ [f_d(y)p(y)] \cdot) = 0 \cap M([f_d(y)p(y)] \succ f_c(y) \cdot) = 0 \end{aligned} \quad (8.8)$$

which gives:

$$\Pi(F_c(y) - f_d(y)p(y) = 0) = \min[ \sup_{u \geq v} \min(\mu_{f_c(y)}(u), \mu_{f_d(y)p(y)}(v)), \sup_{u \geq v} \min(\mu_{f_d(y)p(y)}(u), \mu_{f_c(y)}(v)) ] \quad (8.9)$$

Thus in a period, a particular level will be optimific (given the assumptions), but it is impossible to predict what it will be, even on average. Thus inefficiency is unavoidable even when considering very long term planning and over very many plans.

#### 8.8.1.2 The effect of bounded rationality.

Even when being able to make the assumptions that there is finance enabling insurance or loans to be available to give stability, and that externalities can be ignored if knowledge is bounded, it is not possible to define an optimum at all; not even by possible and necessary functions.

If rationality is bounded, investors are not able to predict the optimal investment given a possible flood protection level. Therefore it is not surprising that it is found in practice that there is generally a change in investment following implementation of flood protection which is not optimific. The result is the 'flood damage paradox' which has resulted in investment change on floodplains to occur after the implementation of flood protection which sometimes does not even produce a net benefit (see Chapter 10). This consequence can be interpreted as the failure of the institution of a market institution on those floodplains because of too high uncertainty. To avoid it, constraints on and guidelines for investment have to be made, i.e. externalities have to be included so as to define the appropriate working of a market. This realisation led to the interest in floodplain management rather than flood protection (see Chapter 10). Thus externalities have been found necessary to be included in economic analysis for floodplain management.



### **8.8.1.3 Rule-based economic analysis for floodplain management.**

The task is to consider the externalities that have to be taken into account so as to create a successful market institution on floodplains. The requirement is stability. As developed in Section 8.7.2.2, stability is expected to occur when the meta-values giving sustainability and biodiversity are held, and can be sought to be implemented by defining an equilibrium of functional interactions between groups (in field 2); human and non-human for human community and ecosystems respectively. The equilibrium attempted to be contingently socially constructed is defined by sets of goals expressed as rules. The goals are defined through interaction with the societies' communities (see Chapters 9 and 10).

Even though specific goals cannot be given, categories that they can be expected to belong to can be derived from the externalities preceding sections have found to be needed to be taken into account. Five categories can be defined:

- (i) Survival/flourishing of each economic entity in a market. Flourishing is defined here as survival plus resources to give to others.
- (ii) Cost effectiveness of management options.
- (iii) Cultural heritage respected.
- (iv) Services needed for society are maintained.
- (v) Ecological relations respected.

Types (iii)-(v) are concerned with the benefits to be gained by improving the human occupation of the floodplain. Type (ii) is concerned with the cost associated, as indicated in Section 8.7.2.2. Types (i) and (ii) involve specifically economic analysis and so are what are covered in the remainder of this chapter. The others are covered in Chapters 9 and 10.

### **8.8.1.4 Survival/flourishing of economic entities.**

For each economic entity there are two aspects to consider.

- (a) the effect on production, and hence income, that a management action may have.
  - (b) the uncertainty of damage and benefits.
- (a) Zoning in floodplains refers to specification of the appropriate use of floodplain areas. It may be information available to economic entities, or legal rules defined by society. Zoning can either promote/allow either increase or decrease in production, depending on what management action is being considered and where the economic entity is situated. Thus zoning affects the income of an entity. For an entity to survive/flourish it must be

able to have a certain income so that it can engage in the reciprocal relations of exchange making up societal structure.

(b) For all the reasons developed in Section 8.7.2.3, uncertainty is unavoidable and has an effect on economic viability of economic entities. Thus even if zoning may promote/allow potentially greater production, the uncertainty present may make the economic entity not survive/flourish. The two aspects can be considered in a rule such as:

*Damage must be acceptable and overall income must be sufficiently positive.*

The rule is multi-objective and so aggregation of measures of the achievement of the two objectives has to be carried out. First, analysis of the means of fulfilling the two objectives has to be carried out separately.

#### **8.8.1.4.1 Definition of acceptable damage.**

When the management action to be considered is a floodbank it is necessary to determine what is the upper limit,  $d_1$ , for damage events that can be coped with by each economic entity.

The events which are viable, partition  $p_d(d)$ , correspond to sphere 1 in Ravetz' typology (see Chapter 6). The upper limit of damage for a single event ( $d_1$ ) is given by the minimum single event which will make the economic entity non-viable. This is related to the available capital ( $C_d$ ) with which to recover damage losses over a period  $T_c$ . The period  $T_c$  is the period that averaging of capital and damage is possible for cash flow requirements. This averaging is the arithmetic mean as it models the process of capital storage and repayments, or premiums and payout, that banks and insurance institutions offer respectively. So  $T_c$  is not arbitrary. It is a real social parameter though likely to be the design period for the management scheme, but could conceivably be less. Also, the upper limit for  $d_1$  is dependent on  $C_d$  which is also a real social parameter. Such an analysis takes the point post-Keynesians make about the need to consider real economic mechanisms. In terms of the semi-open system model developed in Section 8.7, it is also necessary to consider how these processes can change and so  $C_d$  (and  $T_c$  if necessary) is defined by a possibility function.

However for a given period  $T_c$  a certain risk is allowable. The allowable risk is partly given by the probability of the maximum event in period  $T_c$  ( $P_m$ ) given by Equation 7.37. Because the parameters  $\beta$  and  $\theta$  are fuzzy, calculations to determine  $P_m$  are also fuzzy.

The risk associated with such an analysis occurs because there may be more than one event in the period  $T_c$  which when summed are greater than the allowable damage in

the period  $T_c$  given by  $d_1$ . Thus what is required is analysis of:

$$P(d_1 \leq D \cap \text{events viable})$$

where  $D$  is the damage resulting from the summed effect of several damage events.

Events which are viable are those which have an individual risk less than  $P_m$ .

A risk level ( $P_c$ ) has to be chosen (it can be fuzzy):

$$\sum_{k=2}^{\infty} P(D > C_d | N=k; d_1 < C_d) < (P_{allow} - P_m) = P_c \quad (8.10)$$

i.e. that risk is less than  $P_c$  that damage is greater than  $C_d$  due to more than one event, given that all individual damage events are less than  $C_d$ . The allowable risk is given by the sum of  $P_c$  and  $P_m$ . Solution of Equation 8.10 requires an adaptation of Equation 8.13 below.

To determine whether or not Equation 8.10 is fulfilled for a particular management option, the possibility functions  $\pi(P_m)$  and that given by the left hand side of Equation 8.10 have to be added together and then compared with the possibility function  $\pi(P_{allow})$ . Once again Equations 5.18-21 are appropriate to use. The non-technocratic presumption is being made therefore it is assumed that it has to be proven that the fuzzy sum of the two calculated risks is less than  $\pi(P_{allow})$ . Thus lack of information, leading to high uncertainty and imprecision will lead to risk-averse actions being taken, including the use of contingency planning.

#### 8.8.1.4.2 Analysis of income.

Analysis has to be carried out for a particular period. This can be considered to be the design period of the management plan. It cannot be longer. Values of damage are simply summed over the period. Adjustments for varying symbolic representation that money has (inflation) are required, but not discounting.

Income received from trading production within a market institution will be imprecise, and increasingly imprecise as the future is considered because of the market environment. It is real information as it is known now. The increasing imprecision has to be discretized. For example yearly for  $n$  years. Then a present sum, including imprecision giving a possibility function needs to be obtained, i.e:

$$\mu_{tot}(I) = \sum_{i=1}^n \mu_i(I) \quad (8.11)$$

### 8.8.1.4.3 Analysis of damage

Expected damage will be uncertain and imprecise. In Chapter 7 it was argued that flood events can be modelled as a Poisson process, where floods can be defined by when streamflow exceeds a threshold, and the governing variable for the occurrence of floods,  $\theta$ , is fuzzy. Damage is a function of flood magnitude so the non-exceedance probability distribution of damage  $D$  over a period is given by:

$$P(d \leq D) = P(N=0) + \sum_{k=1}^{\infty} P(d \leq D | N=k) P(N=k) \quad (8.12)$$

The probability distribution of damage given that flood events occur ( $p_d(d)$ ) is given by  $p \circ f_d^{-1}$ , where  $f_d(y)$  is the damage/stage relationship and  $p(y)$  is the conditional pdf for stage given that a flood event has occurred.  $p(y)$  is given by:

$$p(y) = \beta e^{-\beta y}$$

where  $\beta$  is the mean magnitude of flood events and is also fuzzy.

The analysis of damage from flooding is analogous to the analysis of erosion potential discussed in Section 7.6. Therefore Equation 8.12 is solved by considering the general solution:

$$P(D | N=k) = \int_0^D f(d_1) \int_0^{D-d_1} f(d_2) \dots \int_0^{D-d_1-d_2-\dots-d_{k-2}} f(d_{k-1}) f(d_k) d_{k-1} \dots dd_1 \quad (8.13)$$

where  $d_k = D - d_1 - d_2 - d_3 - \dots - d_{k-1}$ . To solve Equation 8.10, Equation 8.13 has to be solved numerically with  $d_1, d_2, \dots, d_k < C_d$ . This means that the minimum value for  $k$  is given by rounding up  $D/C_d$ .

As outlined in Chapter 7, the result from Equation 8.12 has decreasing relative uncertainty as the period increases, but increasing imprecision. The intuitive approach outlined in Chapter 5 to synthesize possibility functions from fuzzy probability is appropriate to use. The result is a possibility distribution of expected damage  $\pi(D)$ .

### 8.8.1.4.4 Overall income.

Overall income associated with floodplain management is simply given by:

$$I_{\text{overall}} = I_{\text{tot}} - D - I_{\text{finance}} \quad (8.14)$$

$I_{\text{finance}}$  is the cost associated with payment to financial institutions to be able to have access to capital  $C_d$  when required. They are all possibility distributions.

Transformations are required to make the calculation of  $\pi(I_{\text{overall}})$ :

$$\text{let } \mu_*(D) = \mu(-D)$$

and  $\mu_*(I_{\text{finance}}) = \mu(-I_{\text{finance}})$

$\pi(I_{\text{overall}})$  has to then be compared with what is an acceptable overall income  $\pi(I_{\text{accept}})$ . As mentioned in Section 8.7 this will be a value obtained by interaction with the public. An aspect of this is the cost of the management plan to economic entities as rates or tax. The comparison involves the use of Equations 5.18-21 to determine whether or not:

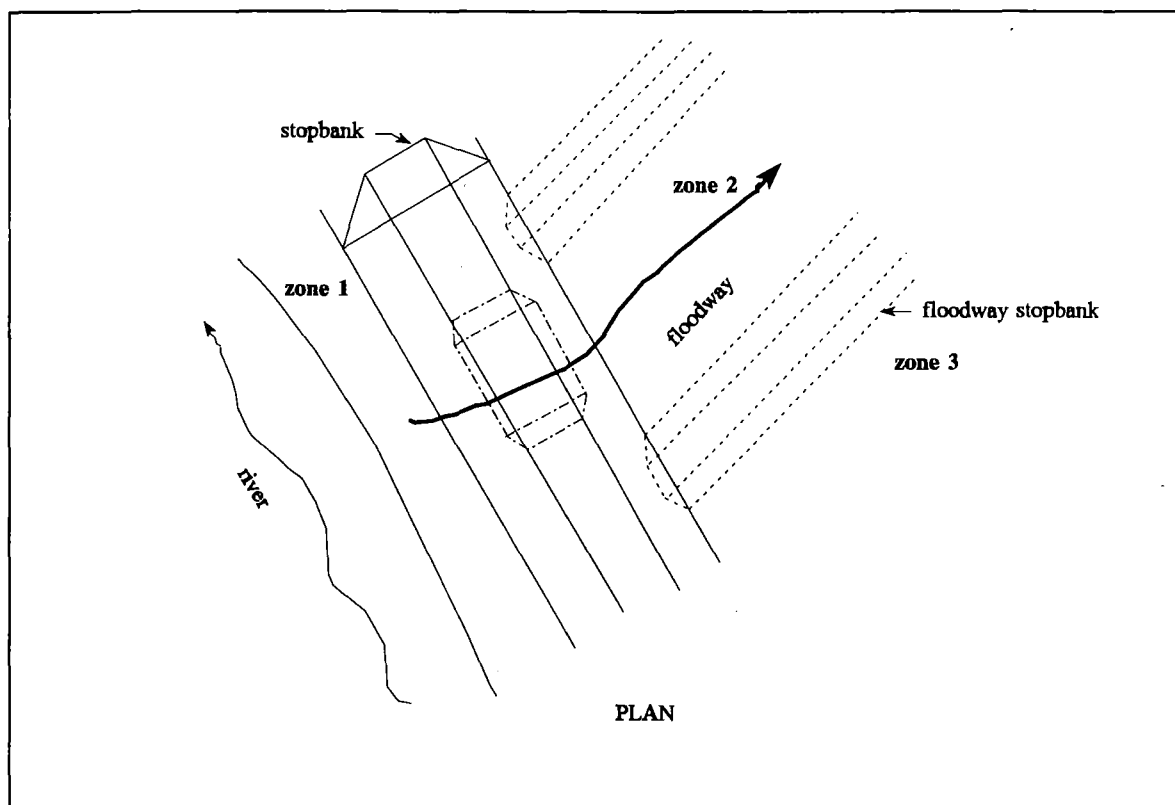
$$\pi(I_{\text{overall}}) \leq \pi(I_{\text{accept}})$$

Once again the non-technocratic presumption is required to be made.

### 8.8.2 Multi-objective management actions.

In implementing the use of floodbanks several zones are defined. In general this results in multiple objectives as more than one economic entity is involved. However in specific analyses an economic entity may use all the zones being considered and so it is single-objective.

It is developed in Chapters 9 and 10 how the process of analysis follows down possible flood routes in discrete steps considering the effect of the flood profile. The most complex situation for each step involves three zones (see Figure 8.6). Zone 1 has a



**Figure 8.6;** Floodplain zones.

threshold defining flood events defined by some low-level event. Zone 2 has a threshold

defined by the height of the floodway causeway. Zone 3 is defined by events above the floodway floodbanks or over the non-floodbank's bank. Zone 3 is split into various subzones depending on the topography.

Flood frequency curves for zones 2 and 3 require to be synthesized from a flood routing model (see Chapter 7).

The three zones partition an analysis of probability of occurrence in the extension of PMRM developed in Chapter 6. Each zone has the analysis of acceptable damage calculated separately. If an economic entity uses more than one zone then the risk associated with damage not being acceptable is given by the sum of the risk associated with each. An alternative is to proportion  $C_d$  to the various zones.

The overall expected damage for a particular economic entity is similarly calculated for each zone separately then added together after having being synthesized into possibility functions.

There will be subzones of zone 3 that do not allow meaningful analysis of summed damage events because the occurrence of events are very unlikely and/or catastrophic. These zones require to be constructed because damage associated is intangible and have their own rules (see Chapters 6,9 and 10).

### 8.8.3 Cost-effectiveness.

There are two parts to consider in cost effectiveness. Both are direct costs.

- (a) The cost of construction of management actions.
- (b) Maintenance costs.

The two are related in the use of floodbanks (see Chapter 7). They are required to be summed together over the design period without discounting, for reasons given previously.

Cost-effectiveness has to compare costs resulting from different possible management actions. This occurs at each specific site and generally for the system. When considering individual sites, cost effectiveness as a function of effectiveness in fulfilling other goals mentioned at the beginning of Section 8.8.1 requires to be calculated. For each degree of goal achievement the set of most cost effective management actions needs to be calculated. This involves comparing possibility functions of cost  $\pi(C_k)$ ; one for each of the possible  $k$  sets of management actions.

Possibility functions must be compared to determine the minimum set where none are significantly lower (see Equations 5.22 and 5.23). From these a possibility function of a minimum set defining cost effectiveness management actions can be obtained. The support of the possibility function is given by  $\Pi(C_k^* < \min^*(C)_*) > 0$ . The core of the

possibility function is given by  $\Pi(C_k^* < \min^*(C)^*) = 1$ .

## 8.9 CONCLUSION

The review of economic theories indicated a need to extend the appreciation of the individual and their responsibilities. Extending the theory in this way enabled ethical concerns to be incorporated through adoption of a social construction theory to frame reconstruction of economic processes. The reconstruction suggested is straightforward and is couched within an overall integrated management decision process and so is not problematic to implement.

The suggested implementation of reciprocity and cooperative functional integration of services and respect for cultural and natural heritage is practical because it is sought to be operationalized within participatory democracy where the public interacts at all stages of management plan development. Thus default actions following theories-in-use to compete can be shown to be unnecessary.

The outlined method allows externalities that come to be known to be relevant to be realistically taken into account. Furthermore, as information comes available, the mathematics involved enables management actions to be implemented more efficiently through the fulfilment of required goals through less risk-averse management, planning and policies being able to be adopted.

## Decision-making

Some commentators (e.g. Hazelrigg 1988) argue that engineering methodology is essentially decision-making. Hazelrigg makes a comparison between decision-making and problem-solving. He argues that engineering is a decision-making rather than a problem-solving method because experience and creative ability which are involved in decision-making and essential aspects of engineering method, are not required in the ordinary meaning of problem-solving. Hazelrigg does not consider scientific creativity to be problem-solving either, because problem-solving is considered to merely involve the following of a prescribed technique. Thus decision-making is linked to activities associated with what previous Chapters outlined as creativity arising from reflexivity. Also because it involves coming to decisions it is holistic as the process involves having to attempt to synthesize together all the parts of the situation to make a decision.

The discipline of decision theory attempts to formalise the process of decision-making. Thus to the extent that the formalisation is helpful in nurturing the process of reflexivity decision-theory is arguably an important part of engineering methodology. There are several approaches which have been attempted. To various degrees the technical, ethical and political implications are able to be taken into account by them. In light of the previous chapters, an acceptable decision-making theory for floodplain management is one which would enable the technical hydrological information, and the political or social and ethical concerns addressed, to be considered and integrated together coherently. Relevant hydrological information has to be woven together with risk and economic reflexive understanding, according to decision-making procedures that are structured by the dimensions and general formulation of logic.

Moffat (1990; p 218) makes the claim that the (formal) decision-making process involves integrating the gaining of technical data and the manipulation of it and other expert knowledge through information technology. However he adds, consonant with Hazelrigg (1988), that the important aspect is the integration or weaving together of information so that a coherent vision is gained.



‘(I)t is important to emphasize that all this apparently useful information is only an aid to the decision-making process. It is no substitute for making clear, accountable decisions in the use of the environment, nor is the use of information technology an excuse for avoiding difficult ethical and political implications associated with using the environment in one way rather than another. Clearly, some of the technical and ethical problems associated with the use of information technology have yet to be addressed before the full potentialities of information technology for environmental management can be realized.’

Therefore the decision-making process as carried out in floodplain management has to focus on how to use information technology to carry out analyses which have to be integrated together. Preliminary development as to what is the appropriate structure to integrate information together has been reviewed in Chapter 5. The formal development of the procedures is outlined in terms of decision theory, planning and management literature in this chapter. The postmodern arguments developed in Chapters 3 and 4 are used to give the dimensions to focus a critical review of the literature. This is well begun by a deconstruction of decision theory as it stands at present.

## **9.1 DECONSTRUCTION OF DECISION THEORY**

There are two aspects to such a critical evaluation of decision-making theories. Firstly the conceptual basis which determines what is taken into account, and secondly, the methodology, especially the mathematical calculus, used to allow computerised handling of the situation by available information technology.

The types of decision-making theories can be classified according to a roughly historical development. The treatment of them in this chapter will accordingly be in that order:

1. Behavioural approaches.
2. Hierarchical models.
3. Expert systems.

From critical review of these a fourth type is developed as a postmodern reconstruction which is acceptable to both the conceptual requirements developed from the postmodern requirement for reflexive coherence as well as the mathematical requirements as developed in Chapters 5 and 8.

### **9.1.1 Behavioural decision theory.**

Behavioural decision theory tries to define formally a way to construct information involving technical information, procedures and responses from those involved. The theory is based on a set of assumptions drawn from the Enlightenment view of autonomous rational human nature (see Chapter 3), and classical economic axioms of 'economic man' (see Chapter 8). The archetypical synthesis was made by von Neumann and Morgenstern (1944) in game theory. The behavioural approach is based within the same paradigm as the SOAR model in risk analysis reviewed in Chapter 6. Information about individuals' perceptions are gained from observation. Dialogue is used only to elicit data. Experimental situations are created to gain information. This can be contrasted to a workshop or hui-type situation using dialogue, discussion and conversation as an analytical process in itself and not just as a means for data collection.

An issue in floodplain management that decision-theory may provide help for is in the combining of the individual awareness of uncertainty into an ethical concern for all those involved. It is a systemic issue because uncertainty in the form of risk data is often technical information given to the public. So approaches need to explicitly concern themselves with technical information as well as individual responses. The social construction of the responses of individuals through 'risk education' has to be considered. Then the conclusion drawn in Chapter 6 that all information needs to be able to be given to promote open communication and inform decisions can be implemented pro-actively.

It has been argued also that dis-information acting ideologically in a coercive way occurs where there is more certainty included in technical information. This is an issue for both technical and non-technical information. So if technical information recognises imprecision about non-technically constructed information which is precise, or vice versa, the issue has to be looked at carefully when proactive social reconstruction is embarked upon. Rigorous analysis of decision-making is required in relation to the issue of uncertainty and imprecision and how to handle it technically.

However to date the issue of individual construction of information (or rational choice) under uncertainty within the wider ethical issue of ordering of individuals' preferences (often called social welfare) is not comprehensively covered. As mentioned in Chapter 7 research programs have existed which look at 'individual rationality under uncertainty' and also 'social rationality' separately but both are extremely problematic even on their own separately. The issue of how to consider social rationality when individuals are making choices under uncertainty is not yet attempted. But it is a central issue in hazard (e.g. floodplain) management. Therefore to adequately make sense of the issue it

is important for decision theory if decision theory is to be helpful.

The problem has been represented in matrix form (see Figure 9.1 adapted from McClennen (1981; p97). The  $A_i$ s are a set of alternatives which are to be ranked and from which a choice is to be made. The  $B_k$ s are a partition of possible events, i.e. a set of mutually exclusive and exhaustive events. So if the  $B_k$ s are measures of uncertainty they are

		$B_1 \dots B_k \dots B_n$
$A_1$	$u_{11} \dots u_{1k} \dots u_{1n}$	
.	.	.
.	.	.
$A_i$	$u_{i1} \dots u_{ik} \dots u_{in}$	
.	.	.
.	.	.
$A_m$	$u_{m1} \dots u_{mk} \dots u_{mn}$	

**Figure 9.1;** Utilities matrix.

probability measures. This is how the situation of individual rationality acting under uncertainty can be modelled.  $B_k$ s can also be individuals making up a society, where  $u_{ik}$ s are their preferences. It is how social rationality can be modelled.

The  $u_{ik}$ s are utilities given within each alternative for each possible event. The utility indices incorporate in some way the uncertainty of the events if the  $B_k$ s are measures of uncertainty. How this is, and should be done, is an issue in the decision theory literature which is not obvious as is shown in later sections. A common behavioural decision theory approach, of determining it as a measure of technical risk (see Chapter 6) is not universally accepted.

There are several assumptions in behavioural theory which can be explored by analysing the above matrix. There are the axioms of ‘economic man’, and there is the assumption called the ‘true thing axiom’ or the ‘independence axiom’ (McClennen 1981). General difficulties with the axioms of ‘economic man’ have been addressed in Chapter 8. Specific analysis is best initiated by considering the ‘independence axiom’:

Where  $B' \subset B$ ,

$$\forall A_i, A_j : \forall B_k \in B - B',$$

$$u_{ij} = u_{jk} \Rightarrow A_i \text{ is at least as good as } A_j \text{ if and only if } A_i|B' \text{ is at least as good as } A_j|B'.$$

(9.1)

In other words the ordering of two alternatives is unaffected by the elimination of columns in the matrix for which the alternatives have the same utility. This means that the problem can be reduced to one of only considering the possible events where the utilities are different for the different alternatives. This axiom is called the ‘independence axiom’ because the utilities within each alternative are able to be considered independent. Context is not relevant. It is assumed that there is no meaning present in the utilities other than what can be considered in the individual  $u_{ik}$ s. It is assumed that there is no

dependence between the utilities which makes it possible that they can be determined separately and out of context. This does not mean that the  $B_k$ s are independent. That they form a partition proves that they are not and is clear when considering that probability measures are given when individual rationality under uncertainty is the issue.

For example, consider a person facing the problem of flooding with various flood mitigation alternatives to consider. The  $B_k$ s are the different possible maximum flood levels that could occur in the period the person is considering. The  $u_{ik}$ s are utility indices within the particular alternative  $A_i$  if the event  $B_k$  occurs. If more than one person is considered then it is the sum of the group's utilities. Different alternatives will allow different degrees of protection to different levels, but at different costs; i.e. the situation discussed in Chapter 8. The utility is the fuzzy net benefit given by Equation 8.3. However past a certain probability of occurrence the flood level will overtop any flood protection and so the flood damage will be the same no matter what alternative is chosen, assuming that the alternatives do not have different zoning restrictions associated with them. Therefore according to the independence axiom these utilities can be ignored in the calculations as to what is the best alternative. This is in effect what was carried out in Section 8.8.1.3. The different alternatives  $A_i$  were the domain from which an optimum was sought and found to be fuzzy. Therefore it can be deduced in continuation of the argument in Chapter 8 that if rationality is bounded then the 'independence axiom' cannot be made.

McClennen (1981) goes on to point out that the independence axiom does not always hold. He argues that this occurs if there is added information (externality) not included in the atomic utilities that is relevant in making a rational decision. This can be appreciated more easily by framing the above situation as that of social rationality where  $A_i$  remain the same but the  $B_k$ s are the persons'/actors' utility evaluations. If the independence axiom is not appropriate then meaning is seen in the structure of the set of utilities for a particular alternative. If the structure has some meaning (adds information) then the relationships between the events are significant. Also because a structure gains relevance in relation to its environment, the context is important. Therefore the utilities pertaining to the events are not independent. The extra information is a structural significance given by the subjects involved as it exists in the socially created interaction of language games socially constructing the preferences of the individuals to some extent. The meaning may be able to be described metaphorically, e.g. in the reconstruction of functional relationships in a society according to an organismic metaphor as developed in Chapter 8. However to avoid them being mere abstractions outside of the language game

they need to refer to a significant rule in a 'language game'. This makes it clearly bounded rationality as a consequence of structural power or social construction is a sufficient condition to make the independence axiom illegitimate. Where bounded rationality occurs an optimific solution cannot be obtained, and so the set of  $A_i$  cannot be ranked, even though there may be full interpersonal comparison of utilities.

To illustrate a situation where the independence axiom is legitimate consider that  $B_k$ s form a domain of possible components in floodplain management strategies. Consider the two alternatives:

$A_1$  - subsidies for stopbanks, flood proofing and no stop banks.

$A_2$  - subsidies for stopbanks, no flood proofing and stop banks.

According to the independence axiom the column 'subsidies for stopbanks' can be eliminated. Therefore as it is conceivable that individual floodproofing may be cheaper, or no more expensive than paying a share in stopbanks, alternative  $A_1$  would be chosen. However it is clear that given the alternatives including the eliminated column, because of the structural relationships between the management components, alternative  $A_2$  would be chosen. So the independence axiom does not hold here. This example also illustrates how the structural significance can be that of social organization and the context given by significant rules in language games. The significant rule is legislation giving national support for regional development.

#### 9.1.1.1 Aggregation algorithms.

Whether the independence axiom is instituted or not, the set of  $u_{ik}$  for any particular  $i$  have to be able to be aggregated, which is also problematic. According to possibility theory there are three generic possible models of aggregation related to three general attitudes toward aggregation of uncertain events, with an infinite number of possible expressions of them. Dubois and Prade (1988) have reviewed them. What is also needed is consideration of when the different attitudes are relevant and what the corresponding axiology is.

Three fundamental attitudes can be represented according to Dubois and Prade (1988). The representations are given by: conjunction, disjunction and averaging. This is most simple when assuming that all the objectives ( $B_k$ s) are of equal importance. This is a special case and the more general case where they are not is covered later.

Conjunction refers to a global evaluation where an action cannot be better than the worst of the individual or partial evaluations. This is the ethos of Rawls' (1971) theory of justice. A min operator is used to carry out the aggregation:

$$\forall u_1, u_2 \quad h(u_1, u_2) \leq \min(u_1, u_2) \quad (9.2)$$

A special case is fuzzy set intersection according to the various MVLs defining this (see Chapter 5). Using fuzzy set properties enables the special case to be extended to any number of arguments to give:

$$h(u_1, \dots, u_q) = \min_{i=1, q} (u_i) \quad (9.3)$$

Disjunction is where the global evaluation is determined by the best of the individual or partial evaluations. This is the ethos of elitist ethics (Kneese et.al 1982). A max operator is used to carry out the aggregation:

$$\forall u_1, u_2 \quad h(u_1, u_2) \geq \max(u_1, u_2) \quad (9.4)$$

A special case is fuzzy set union carried out according to the various MVLs which extended to any number of arguments gives:

$$h(u_1, \dots, u_q) = \max_{i=1, q} (u_i) \quad (9.5)$$

Averaging is a compromise between these two:

$$\min < h < \max \quad (9.6)$$

There are many ways developed to express a continuum between disjunction and conjunction. A general solution reviewed by Dubois and Prade (1988) is:

$$h(u_1, u_2) = k^{-1}((k(u_1)+k(u_2))/2) \quad (9.7)$$

An example is if  $k(u) = u^\alpha$ ,  $\alpha \in \mathbb{R}$  which gives a set  $h_\alpha(u_1, u_2)$  with special cases given by Table 9.1:

$\alpha$	$h_\alpha(s,t)$
$-\infty$	$\min(s,t)$
-1	$2st/(s+t)$ harmonic mean
0	$(st)^{0.5}$ geometric mean
1	$(s+t)/2$ arithmetic mean
$+\infty$	$\max(s,t)$

**Table 9.1;** An averaging rule generating function.

The arithmetic mean is the calculus used in unweighted utilitarian analysis. The main point is that there is an infinite number of ways to try to model an averaging attitude to aggregation. Also a general solution can be extended to any number of arguments:

$$h(u_1, \dots, u_q) = k^{-1} \left( \frac{1}{q} \sum_{i=1}^q k(u_i) \right) \quad (9.8)$$

#### 9.1.1.1.1 Aggregation of objectives with unequal importance.

As mentioned above, all of the above methods assume that all objectives (individual or partial evaluations) are of equal importance. If this is not the case then another dimension is added. Dubois and Prade (1988) have also made a non-definitive review of the issue of aggregation of unequal importance. An important point they make is that the most common version is very problematic, i.e:

$$u_w = \sum_{i=1}^q p_i u_i, \quad \sum_{i=1}^q p_i = 1 \quad (9.9)$$

where  $p_i$  are the weightings and  $u_p$  is the global utility. It is the version used in social welfare functions and suggested by Schrader-Frechette (1985b) for use in ethically weighted CBA (see Chapter 8) which uses an arithmetic mean calculus with an averaging attitude (see Chapter 8). Probabilistic definition of weighting is used therefore assuming that individual or partial evaluations of weightings are elemental and precise. The application of weightings implies that some extra information or structure (externality) is present and is shown by how the transformation of the set of  $u_{ik}$  to  $p_{ik}u_{ik}$  will counter the independence axiom if  $p_{ik}$  varies for any given  $k$  over the range of  $i$ . However the structure is modelled by a random generator metaphor meaning that the significance of the various influences occur randomly. Also if the weighting is applied independent of alternatives  $A_i$ , the independence assumption still holds which must mean that the extra information is disinformation or arbitrary structuring as Blaug (1980) argued (see Chapter 8).

On top of this, Dubois and Prade (1988) also argue that individual magnitudes may be incommensurable. Schrader-Frechette (1985b) has also reviewed such criticism and accepted it. If it is accepted however the use of Equation 9.9 is incoherent, as a utilitarian analysis should not be used whether or not weightings are used (see Chapter 8). However it is still attempted, and as mentioned in Chapter 8, Schrader-Frechette (1985b, 1987)

argued for it if nothing better could be found to be used as a tool. Dubois and Prade suggest what a possible improvement may be by defining the pertinence of each partial evaluation or objective for the global evaluation or objective as a possibility value ( $\mu_{\pi}(u_i)$ ) rather than a measure of utility itself, thus overcoming the incommensurability problem (see Equation 8.10).

$$\sum_{i=1}^q p_i \mu_{\pi_i}(u_i) = \mu_D(u_w), \quad \sum_{i=1}^q p_i = 1 \quad (9.10)$$

Probabilistic weighting is still held however but it is no longer assumed that the individual or partial objectives are atomic and precise. Never-the-less a utilitarian analysis is still carried out and so the incoherence remains. But this can be overcome by adopting another suggestion of Dubois and Prade given by Equations 9.11 and 9.12:

$$h_N(u_1, \dots, u_q) = \min_{i=1, q} \max(u_i, 1 - \pi_i), \quad \max_{i=1, q} \pi_i = 1 \quad (9.11)$$

$$h_{\Pi}(u_1, \dots, u_q) = \max_{i=1, q} \min(u_i, \pi_i), \quad \max_{i=1, q} \pi_i = 1 \quad (9.12)$$

where values of  $u_i$  are normalised to belong to  $[0,1]$  and  $\pi_i$  are weightings. The possibility and necessity global evaluations are special cases of measures of degrees of compatibility or truth values as to whether the global objective is expressed.

If all partial evaluations or objectives expressed in Equation 9.11 are of equal importance (i.e.,  $\forall i, \pi_i = 1$ ) then Equation 9.11 is equivalent to Equation 9.2. Similarly Equation 9.12 is equivalent to 9.4. So if all objectives are of equal importance, the supremum of possible results for the global objective for which there is sufficient evidence is elitist ethics, and the infimum solution which is necessarily correct is Rawlsian ethics; with anything in between also being viable.

Examples of aggregation to give degrees of compatibility as to whether the global objective is expressed or not are found in Chapter 7 in Section 7.4.1 where the global objective is that the model is adequate in terms of both pertinence and success.

Dubois and Prade (1988) also point out that Equations 9.11 and 9.12 refer to a type of MVL implication of the rule, 'if  $i$  is important then it is attained.' So Equations 9.11 and 9.12 can be even further generalised by using the full range of possible MVL implications.

Finally Dubois and Prade (1988) point out that objectives of unequal importance do not have to be determined according to a single set of like rules as given in Equations 9.9-



12. Different rules can be used for different subsets of the domain of partial objectives. If this is done then the situation is one development of pertinent Expert Systems where the search for single aggregation algorithms is not carried out (see Chapter 5) This approach is developed in Section 9.1.4. Any combination of conjunction, disjunction and averaging in rules between the facts given by valid evaluation and/or objectives is possible.

#### **9.1.1.1.2 Appropriateness of aggregation methods.**

A conclusion to be reached is that the calculus for aggregation of objectives that are not equally important is open-ended and is flexible enough to reflect rules that can span the realm of ethical theories. The decision about what is the appropriate model is dependent on context. It can include any type of rule and any type of calculus. There is no technically correct or essentially correct method. Dubois and Prade (1988) even point out that the expected understanding that a conjunction or linguistic 'and' operator is adequately modelled by a min operator (e.g. suggested by Blockley 1980) is not correct in all instances.

Therefore in keeping with but extending McClennen's (1981) observation that appropriate models are somewhere in between the two poles of unweighted utilitarianism and the Rawlsian conjunction rule, the conclusion reached here is that the important task is to have the methodology flexible enough and open enough to create pertinent sets of rules that are contextually appropriate. This need not necessarily involve global aggregation based on universal ethical principles. Rules for specific application that are part of any system reconstruction socially constructing a language game may be appropriate.

Once again this emphasises the importance of a SSM-type methodology involving dialogue to synthesise non-naturalistic intuition and contingently held naturalistic principles.

#### **9.1.1.2 Types of behavioural theories.**

There are two broad categories of behavioural decision-making theories which occur and parallel technical risk analysis and neo-classical economic theory. They are optimisation and bounded rationality.

##### **9.1.1.2.1 Optimisation methods.**

Within optimisation approaches there are several ways that uncertainty is attempted to be handled. The most straightforward is that by Edwards et al. (1988) who argued that utilities can be given for situations where risk is taken into account by the person without

the distinction between utility and uncertainty having to be made explicit. No calculus of uncertainty is considered necessary. Edwards et al. (1988) argue their case along the lines that other approaches are based on arbitrary assumptions and lead to unnecessary mathematical complications. However no justification is made for why a utilitarian aggregation technique for social rationality is used. It is presumed after dissociating analysis from any attempt to ground theory in theories attempting to provide coherent calculi.

Keeney (1988) attempts to solve the issue of non-independence raised previously by defining fundamental preference functions which he assumes exist at the basis of all dependencies and hence structural relationships or holistic meaning. He does not justify this assumption. It appears to be based on an uncritical acceptance of 'Enlightenment' views on rationality and the neo-classical economic paradigm, i.e. a rationalist epistemology assuming autonomous self-interest maximizers with there being no social construction of reality or selves. The assumption is the same as that of the SOAR model in risk analysis and that of neo-classical theory in economics.

For Keeney every concern can be considered to be in terms of objectives, and the objectives can be considered to be purely the subjective concern of the individuals. They are considered to be in no way socially constructed through ideology or even collective social goal definition exercising moral freedom. Further, they are assumed to have a linear utility function that is taken to mean that they are then purely subjective in accordance with a 'rational' self-maximizer. Occurrence of non-linearity in utility profiles is taken to mean that more than one fundamental preference function is involved. Only when independent fundamental utility functions are obtained is the situation considered analyzable for either individual rationality under uncertainty or social rationality. This is mathematically correct and is analogous to the definition of 'storms' and 'streamflow events' in such a way that they are independent and so can be used within a stochastic model. However for Keeney it appears to be taken as an essential reality rather than as a pragmatic abstraction (see Chapter 7).

Finally Keeney assumes that there is complete inter-subjective comparison and an unweighted utilitarian rule is used for aggregation, i.e. an averaging attitude with all objectives being of equal importance is always appropriate irrespective of context.

Keeney's approach is an example of essentialization. It recognises that dependence occurs, but fails to address valuable information which may be present in it. Rather it is seen as a failure in the analysis. Keeney's (1988) view may be useful however if instead of making his assumption that fundamental utility responses really

occur and non-observation of them is due to imperfect analysis, it is recognised that such independent and linear utility profiles may actually be able to be defined for certain situations where institutional or other system effects enable the random generator metaphor to be used. But where the random generator metaphor is not appropriate then information given by utilities involving other types of analysis are required because the assumptions of independence and linearity are inappropriate.

The operationalisation of Keeney's approach, because of his essentialist/rationalist assumption implies that probabilities can always be determined, and are given by subjective probability techniques. However in keeping with the behavioural approach, the subjective probabilities have to be gained objectively from observation. This is carried out by experiment-type created situations using betting games that allow valuing to be observed. Because rationality as optimisation is assumed, it is also assumed that players will bet with money in a way which reflects their subjective appreciation of the probability of success, as well as magnitude of payoff. The use of money is used to attempt to assure commensurability between players' utilities. Therefore it can mathematically allow the assumption to be made that allows for a utilitarian analysis to be carried out.

Note how this use of subjectivity is different to that used in fuzzy sets where individuals or groups create a representation of uncertainty themselves and communicate it symbolically as part of a wider expression of moral freedom. The use of fuzzy sets involves a process of dialogue rather than objective third party analysis of unrelating subjective valuers using money. This very specific situation producing the information for operationalisation of the independence assumption indicates its very limited appropriate use.

#### **9.1.1.2.2 Bounded rationality.**

In contrast to the optimisation approach of Keeney, in bounded rationality method there is explicit recognition that preferences and utility functions are never able to be determined independent of other effects. This is held as an epistemological principle.

The theory of bounded rationality, as initially formulated by Simon (1957), claimed that a global optimal decision is never made and seldom ever could be. Furthermore he claimed that people do not even try to. The theory argues that people rather accept a solution that contingently 'satisfices' them after perhaps some scoping of possibilities. So there is no need to try to justify any particular decision rule for the best or appropriate aggregation according to this approach. Rather it is a matter of what techniques are socially accepted. Bounded rationality is still however within the behavioural paradigm

because the theory concerns itself with observation of how people make decisions rather than the recognition of it explicitly as a social construction.

Of importance is that because rationality is not assumed to be perfect, learning is a never-the-less relevant concern. Such concern is not relevant for optimisation models because there can be nothing to learn. However in bounded rationality theory there is always the possibility of extending the bounds so that more is known to be taken into account, thus giving a better decision that satisfies.

March (1988) has outlined four types of rationality associated with learning within the bounded rationality approach.

1. *Limited rationality* which is the point Simon made.
2. *Contextual rationality* which refers to the inherent dependence of all valuations on other issues and hence their relativity. This refers to how learning involves seeking coherence and is required to be holistic and reflexive as explored in Chapters 3,4 and 5.
3. *Game rationality* which refers to the collective process of social rationality as constructed from individual (bounded) rationality through various means but without defining the governing social rationality's rules. Neo-classical economic axioms and expressions in game theory (see Chapter 8) are an example because neo-classical economic theory defines how the axioms are socially constructed by institutions.
4. *Process rationality* which refers to how decisions can involve procedural rules rather than explicit attention to outcomes. This is a feature of the postmodern characterization of social organisation as language games determined by rules, because it is recognized that outcomes are often indeterminate and so there has to be instead a reliance on monitoring (see Chapter 4).

All of these analyses of rationality focus on the individual making calculated decisions. This is the Enlightenment approach of autonomous individual human nature and held to be so by bounded rationality theories as much as by optimization approaches. March (1988) points out however that another type of rationality is also discussed which does not fit into this overall approach. It is the systems basis for rationality, for example held by radical constructivism (see Chapter 4). However March still only takes a behaviourist approach to it and defines functions through observation rather than explicit social construction. The systemic approach links the bounds of rationality to the functional role that particular groups have in society, and hence the role that rationality has for the individuals in their groups. Accordingly March argued that the distinction between a systemic rationality definition and those associated with learning is that systemic rationality is not intentional, whereas learning is. A social constructionist approach can

dispute this. The notion of systemic reflexivity developed in Chapter 4 which links the individual to the whole in ontological growth transcends this dichotomy.

What is being referred to in both the learning and systemic approaches is a dialectical relationship between individual creativity and the language game which is to a large extent deterministic. What is different in the social constructionist approach developed here is that the dialectical tension between these two poles is characterized by reflexive spheres producing co-evolution involving morphogenesis of the systems. By contrast the rationality of learning is only ever learning so as to better play the existing language game. Without the critical dimension of how to extend rationality and hence change functional relationships in society, the learning aspect of bounded rationality theory refers merely to the process of social integration; how to learn so that the rationality is appropriate for the functional roles expected of decision-making by the groups. This is assumed because rationality is not considered to be creative because it is assumed to be institutionally framed in a fixed discourse rather than conversation. Thus the possibility of following new rules is not considered. Reflexive thought (deconstruction and reconstruction) is not recognized. That this point is not picked up by commentators following the bounded rationality tradition is however not surprising because reflexive thought is not part of the behavioural paradigm. The paradoxes of reflexivity do not allow objective observation. Reflexivity is a process occurring in creative meditation and discussion; learning made through personally engaged dialogue rather than detached observation (see Chapter 3 and 4).

The consequence of the lack of recognition of the role of reflexivity in bounded rationality theory, and all other behavioural theories, means that the creative aspect of decision-making Hazelrigg (1988) considered to be so important is left out. It also means that concern for the second-order feedbacks, observed in a system analysis, resulting from conflict and ethical awareness producing morphogenesis are not taken into account. A consequence is that the role of policy to reconstruct the system's operation or social rationality as done in SSM, and the postmodern development made in Chapter 4, is not addressed.

A consequence, as March (1988) points out, is that the distinction between the concern for individual rationality and social rationality is obscured in bounded rationality theory. The issue of aggregation is not explicitly addressed. Social rationality is metaphorically assumed to reflect individual rationality and so it is assumed to be a collective summing of individual rationalities; the playing out of a language game according to the same rules. The hierarchical structure of model-making is not

recognized. Symmetry is assumed.

An exception is Forester (1985, 1989) who has however specifically developed bounded rationality theory in a direction so as to deduce how to extend the bounds of rationality based on a critique of existing social structures through application of critical social theory (see Chapter 4). Because his analysis does have some features helpful in reconstruction of systems it is used in Section 9.2.

#### **9.1.1.3 Game and Conflict Theory.**

Classical game theory was begun by von Neumann and Morgenstern (1944). It was a revolutionary theory concerned with the problem of individual rationality in face of uncertainty. It took decision-making away from trying to justify objective probabilities, by a shift in focus on to individual subjective decision-making that is objectively measured by third parties.

Its significance for decision-making is how it uses Enlightenment models of individual rationality linked to economic man axioms in such away that the social rationality issue was attempted to be defined by relating all results to individual rationality calculations made according to rules, thus making games which always have an orientation toward optimising individual self-interest.

In consideration of social rationality, Game theory has been developed recently to try to consider the issue of conflict. These are relevant for the review and reconstruction being carried out here. There have been two developments to this: metagame and hypergame theory. The rationale for them both is that conflict can be overcome through achieving stability where everyone is 'rational' in the sense of optimising self-interest, thus giving Pareto optimum solutions to multi-objective analysis (see Chapter 8).

##### **9.1.1.3.1 Meta-game theory.**

A cross product of possible options for all the players form the domain of possible games. Certain rules or assumptions however enable the domain to be limited to a subset of the cross product. Plausible solutions or 'equilibria' are then given by the non-inferior sets in the attempt to model politically feasible events assuming individual motivation to maximize self-interest.

As well as determining the non-inferior set, preference functions for each player for the possible games are made so as to clarify the various attitudes players have about the plausible solutions. Hence the elements of a non-inferior set can be ranked for each person, thus allowing comparison. However no global ranking is attempted. McBean

and Okada (1988) point out that meta-game analysis does not produce learning except in the clarification of attitudes.

### 9.1.1.3.2 Hyper-game theory.

Hyper-game theory, unlike meta-game theory, does seek to produce some learning. The bounded rationality of players is modelled. The aim of it is to produce a bargaining situation to seek a non-zero-sum solution, i.e. it seeks to find a solution which benefits all in a way better than litigation could, while recognising that litigation is always a possible option. However if litigation is sought it is seen as a failure.

The basis of hyper-game theory is the recognition that different actors or players perceive the situation differently. In this way it is similar to the phenomenological approach taken by SSM (see Chapter 4). However a behavioural (positivist) approach is used instead, where differences in perception are defined as various types of misperception, as in the SOAR model in risk analysis (see Chapter 6).

Using the terminology of Hipel and Dagnino (1988), hyper-game theory exists on three levels. A hierarchy of types of hyper-games occur. They are 0-level hyper-games termed  $H^0$ , 1st-order hyper-games termed  $H^1$ , and 2nd-order hyper-games termed  $H^2$ .

$H^0$  are games played without 'misperceptions' and are equivalent to meta-games.

$H^1$  is assumed to have misperception present which distinguishes it from  $H^0$ .  $H^1$  forms a set of  $H^0$ , describing the set of perceptions each player has about the expectations other players have, i.e.:

$$H^1 = \{H^0_1, H^0_2, \dots, H^0_n\}, \quad \forall i \exists i,j: H^0_i \neq H^0_j \quad (9.13)$$

It can also be described by a 2-dimensional matrix where  $V_{ij}$  is the expectation player  $i$  has about player  $j$ 's preference vector.

In  $H^2$  there is awareness of 'misperception' as well as misperception occurring. So there is a set given by:

$$H^2 = \{H^1_1, H^1_2, \dots, H^1_m\}, \quad \forall i \exists i,j: H^1_i \neq H^1_j \quad (9.14)$$

It can be described by a 3-dimensional matrix where  $V_{kji}$  is player  $i$ 's interpretation of player  $j$ 's understanding of player  $k$ 's preference vector.  $H^2$  means that there is misunderstanding of other players misperception. Hypergame analysis carries out 'stability analysis', once  $H^2$  has been defined, for both individual and overall cases. Individual stability refers to whether or not a Pareto improvement can be made for an individual. This occurs for both non-cooperative games, e.g. market operations, and cooperative games e.g. bargaining. From the set of individually perceived equilibria,

optimum strategies are decided upon by each individual. The Cartesian product of the optimum strategies for each player forms the domain of overall stability analysis. 'Equilibria' are found from among these to determine the feasible options.  $H^2$  analysis is carried out to review the domain for overall stability. The transfer of information is aimed to improve the equilibria (individual as well as overall) that occur.

$H^2$  introduces the notion of trying to resolve conflict by being aware of bounded rationality. This is also what the interaction between spheres 2 and 3 involve, as developed in Chapter 4, except that with hypergame theory an essential human nature and objective reality is assumed and defined therefore social construction and even the systemic aspect of bounded rationality is not considered. Symmetry is assumed.

The difference between  $H^1$  and sphere 2 situations is instructive.  $H^1$  conceives of differences in perceptions as misperception causing problems in bargaining, whereas the approach developed in terms of systemic reflexivity in previous Chapters accepts that differences can occur which complement each other to produce an overall integrated social interaction of functional roles. The aim of the wise directing of social construction is to explicitly nurture this functionality. Note that in this latter formulation, boundedness is not seen as ignorance, but rather as expertise which does not make the actors incapable of also perceiving the whole and the functional integration that they are part of. In fact through their conscientious application of their expertise they can expect to grow ontologically to become individuated to do so. The feedbacks from conflict arising in sphere 3 to produce learning to reconstruct better social integration in sphere 2 is a co-evolutionary process. In  $H^2$  feedback about 'misperception' is still seen only as learning so as to improve bargaining.

The differences highlight a fundamental limitation in meta-game and hyper-game theories. It occurs because of the use of non-inferior sets to overcome conflict. It is a type of rationality where context and hence the guiding rules of bargaining are not made reflexively explicit nor criticised. A consequence is a fundamental incoherence. Argyris (1982) points out that if people are self-interested then they will try to deceive and the result is counter-productive results. They do not in fact accept a non-inferior set as a solution set. It is not a misperception needing learning for it to be overcome. It is an explicit perception chosen for the short-term benefit first-order feedback gives. Alternatively if people are not self-interested then an inferior set may not be an acceptable solution either.

In comparison, a SSM approach while recognising  $H^1$  and  $H^2$  games as a possible feature of occurrence in sphere 2 and 3 respectively, attempts to produce solutions based



on coherence of understanding through dialogue. Solutions are sought through pro-actively seeking a consensus based upon an agreed narrative defining social goals rather than through an analytical approach assuming individual self-interest to be played out within pre-defined and ideologically masked institutions. However it is to the credit of hypergame theory that cooperative as well as competitive games are institutions that are considered possible. But it is still arbitrarily limiting the possible social construction of organisation.

The postmodern social constructionist argument developed in previous chapters goes on to say that wisdom incorporating reflexivity can give a non-relative basis for seeking consensual decisions about the contextually relevant social goals, which potentially can create a more stable situation than the solution of a non-inferior set. Explicit integration into the process of change is sought which allows long-term adaptation or sustainability through 'enlightenment' by second-order feedback so ontological growth occurs. Integration and caring creates trust and social relationships of community which involves giving and sacrifice, and thus 'inferior' solutions.

An attempt has been made to model caring and sacrifice as enlightened self-interest (e.g. Rescher 1975). The consequence is a set of  $n$  equations with up to  $n$  variables to describe a situation. However if  $n$  is greater than 2 and the interactions are non-linear then the result is potentially mathematically chaotic. If this is the case the conclusion is the same as that made in the review of economic theory where such results are found (see Chapter 8). It has to be concluded that pro-active consensual decision-making using moral freedom reflexively is required to be carried out rather than making objective analyses as carried out in behavioural theory.

The postmodern solution in contrast is based on an appreciation of what actually produces social stability, i.e. inter-personal relationships of trust and pro-active moral freedom engaged to achieve functional integration cooperatively, respecting and appreciating the different expertise all have. Therefore it is a direct approach. The postmodern view expects that an institution expecting optimisation of self-interest by players will not be expected to produce stability even if a non-inferior solution is kept unless it is done only as part of a functional integration which is also appreciated. As mentioned in Chapter 8, it will not even produce the needed stability to produce viable markets or bargaining situations. The institution has incoherent values, or requires balancing of opposing values which is not made explicit. It is precisely the coherence that balance requires, that the SSM process involving reflexivity seeks.

Never-the-less much insight into the problem of perception is given by hyper-game

analysis, which is very helpful in understanding situations explored by SSM.

#### 9.1.1.3.3 Other 'game' theories.

As mentioned above, the development of classical game theory has been linked to the definition of types of interaction which produce 'game rationality'. Hardin (1990) elucidates this and argues that there are three main categories of games: conflict, coordination and cooperation.

Conflict is the type of situation defined by sphere 3 and what H<sup>2</sup> addresses, e.g. litigation and political activity. Coordination is where each party gains by the other, e.g. laws to produce functionally operating services. It is what is achieved in the functional roles integrated into a whole in sphere 2, e.g. successful zoning of a floodplain. Cooperation is a mixture of conflict and coordination, i.e. coordination open to conflict to correct it. Reciprocity is an example (see Chapter 8). This adds clarification to the view developed in Chapter 8 that markets require some social planning to be successful and perform their appropriate social function, i.e. some coordination is required.

Thus both cooperative and non-cooperative games defined by Hipel and Dagnino (1988) in hyper-game theory are cooperative games according to Hardin's (1990) typology. Another classification by Billet (1992) of cooperative and competitive games, which reviews economic literature in its use of the term, corresponds with Hipel and Dagnino's (1988) classification of cooperative and non-cooperative, and agrees with the typology developed in Chapter 8 based on the work of Schwartz (1986).

The value of Hipel's analysis is that it enables the institutional dimensions to games to be appreciated which are often ignored or ideologically hidden, e.g. in a competitive market institution. In the task of reconstruction carried out in Section 9.2 the institutional dimension has to be understood and so Hipel's analysis is used.

But the type of 'game' theory most reviewed in this research has been that of language games stemming from the work of Wittgenstein (see Chapter 4). The common use of the word *game* may not be purely coincidental because there is a substantive common basis. The common basis is that the assumption that there are essential views is not held. Where they diverge is that for Wittgenstein and the social science tradition developing from it, the focus is on the existence of games defining the actions of the individuals in a systemic way, thus making intent or goals functionally integrated and socially constructed. 'Game theory' rationality is the exact opposite. The institution of self-interest is hidden by having intent essentialised and always that of self-interest. The inversion of the roles of fields 1 and 2, as explored in Chapter 8, occurs.

#### **9.1.1.4 Inadequacy of behavioural theory.**

According to the analysis in Chapter 4, social relations are seen to exist within 'language games' socially constructing human nature and worlds/reality. Reflexive understanding leading to creative construction of language games leads to nurturing of inter-personal relationships, making up trust and community of caring and responsibly formed social structures. Dependencies existing in the social rationality issue therefore involve the perception of meaning, and communication of it within language that both reflect and create the meaning and dependencies.

Not surprisingly then the 'solutions' to the two negative results to the research McClennen (1981) reviewed (see Chapter 8) involved an inclusion of degrees of communication. Without allowing some communication there can not even be a coherent behavioural decision theory. The question remaining to be asked however is, what is the actual communication which can potentially occur and produce the best social rationality in any particular situation? It is arbitrary to merely assume the minimum amount of communication necessary to produce a possible solution to impossibility theorems, as behavioural theory does, unless there may be some argument given for minimum communication. However the ethics and sociology literature reviewed in Chapters 3 and 4 suggest the opposite, i.e. that the more communication the better. Therefore it is better to include what does occur and what can possibly occur, so that better possible solutions can be sought. Then if what produces better solutions can be clarified, effort can be constructively made to nurture the type of language games which produces the best results. It has already been argued that the nurturing of communication within participatory democracy using moral freedom helps in the gaining of wisdom which is arguably the best strategy.

Further when the full expression of the role of communication and hence learning is not included in an institution, theories act as self-fulfilling prophecies through symbolic violence that work by limiting information. In other words they create taboos: they create ignorance for social control (Smithson 1991). For example in neo-classical economic thought there is a taboo about considering communication and interaction which occurs outside of market signals (see Chapter 8). It does not fit within the paradigm of fundamental concepts making up the theory. It is because of this that neo-classical theory is criticised as being ideological (e.g. Bromley 1990). The taboo is seen to act as symbolic violence within the language game resulting from the theory. The arbitrary diminishment of the role of communication which occurs is an example of essentialization where idealisations are made and accepted as reality, thus masking the uncertainty and

imprecision. The need for individual reflexivity, dialogue (conversation) through recognition of intuition and feeling to critique any intellectual formulation is obscured. What is missing in any such naturalistic theory is reflexive conversation about existing limitations to communication, and recognition of different 'worldviews'. When such theories are used the institution using them exerts a degree of symbolic violence through its rulings. Tribe (1972) has analyzed application of behavioural decision-making theory in relation to whether it is ideological in such a way. He concluded that it is inconclusive in general as sometimes the theory is an appropriate one to apply, but that it certainly can be so when it is inappropriate.

#### **9.1.1.5 Modelling structural dependencies.**

When social rationality is considered, with the individuals involved also facing uncertainty and hence unable to give exact utility values or functions, the situation is mathematically equivalent to the utilities of the individuals in social rationality not being independent of each other. The methodological tools available to handle this situation are the full range of aggregation models. What is required is to use the appropriate one in terms of the types of dependencies occurring. The dependencies are the social structures revolving around trusting relationships created to help cope with uncertainty (see Chapters 4 and 5).

As outlined in Chapter 5 there are many possible MVLs which attempt to allow rational thought about uncertainty. A probabilistic logic is only one such case. The limitation of behavioural decision theory to only using probabilistic logic is likely to merely be a historical accident because other logics are less well known and less taught. It is also possibly why the independence assumption for rationality in face of uncertainty became so entrenched. If however other MVLs are used then different axiomatic formulation is possible and the independence axiom in behavioural theory is not a requirement.

The reconstructive aim of this chapter is to develop technical modelling of social structures as part of an SSM process. The reconstruction aims to use trust to cope with uncertainty, and hence to explicitly face the systemic social construction of dependency. With such modelling it is possible to integrate technical information relevant to floodplain management with social concerns into a decision-making algorithm.

It can be argued through incorporating modus tollens arguments (as suggested by McClennen: see Chapter 8), that the use of probabilistic logic is appropriate for only certain situations and that these can be defined. Similarly other situations require other

MVLs. If appropriate MVLs and hence mathematical calculi are determined, then modus ponens deductions about what rules are appropriate and modus tollens conclusions about what type and calculus are not appropriate can be sought to be reconciled as complementary parts of the problem. Appropriate mathematical methodology should enable modus ponens deductions to be made from axioms to produce the ethical conclusions that modus tollens arguments start from to deduce what axioms are inadequate when a situation changes. Tension will always exist because no formulation can be expected to ever be perfect. All formulations are contingent and the dialectic of deconstruction and reconstruction is always present in co-evolution. Also there may not only be one calculus that is appropriate. The tension is the second-order feedback to reflexively evaluate what are the appropriate formulations of axioms and algorithms. This occurs within a SSM process to synthesise ethical intuition and intellectualization through dialogue openly facing conflict. The task is to attempt to match models with the situation in as flexible a way as possible. To do this requires overcoming unnecessary constraints. These constraints can be ideological. In particular the use of behavioural decision-theory assumes independence.

Therefore models other than behavioural theory need to be considered. The aspects that are appropriate to consider are how learning, reflexivity and communication are integrated as these. These are the areas where behavioural theory is problematic.

### **9.1.2 Hierarchical methods.**

A hierarchical approach has as its simplest expression a Rawlsian-type ethics as the basis for a decision rule. Here there are distinct levels defined which allow comparison between the levels. But there is not the ability to achieve comparison between all the levels thus enabling full interpersonal comparison of utilities. What can be decided is whether or not an alternative is able to be chosen over another through the rule of comparing one level at a time; starting with the first until an inequality occurs. The values determined at that first priority determine the decision. If these are equal then the decision goes to the level of next highest priority and so on. Conceptually these levels of priority are able to be defined by the terms 'needs' (highest priority) and 'wants' (second and lower priorities). A Rawlsian analysis is an accurate modelling when these terms are considered to be distinct. If any two or more alternatives fulfil all the defined needs then they have equal utilities. So the decision is based on the next level of highest priority wants, and so on.

A strict Rawlsian approach is within the behavioural paradigm however. But if

goals are considered to be obtained through cooperative expression of moral freedom involving dialogue then it ceases to be. The following discussion does not assume that the goals are defined according to objective analysis as carried out in behaviourist theory.

#### 9.1.2.1 Needs and wants.

The difficulty arises in the attempt to define what are needs and what are wants and to do so precisely. It is possible to try to define needs as those that are necessary for the creation of the conditions for choice (e.g. Goldberg 1985). Such a meta-value promotes the ideal of increasing system flexibility which is the principle for achieving adaptability and sustainability (see Chapter 4). Hence *needs* refer to the fundamental structure required to achieve integration. Thus the hierarchical method of Rawls refers to integration into a particular hierarchical level in a system *appreciation* (see Chapter 4). To achieve integration of the various systems levels (e.g. human community and ecosystem) require Rawlsian hierarchies to be developed for each level of the systems hierarchy. i.e. a nested hierarchy if hierarchies are required. However this transfers the issue to one of how to define meta-values. The argument developed in Chapters 3 and 4 suggests an approach to take. An appeal is made to wisdom expressed as responsibility by authorities in a system that is reflexively open to consider political and ethical issues as expression of meta-values that the publics are insisting need to be addressed for any particular system level.

So to define needs as those necessary to create conditions for choice is necessary but is not sufficient. A sufficient approach requires to allow dialogue, thus enabling the issues the publics consider to be important, to be raised so as to seek consensual decisions as to what the needs are. This introduces however the issue of social rationality. Dialogue is communication which takes the concern out of the bounds of behavioural theory. This means that the use of a Rawlsian hierarchy is not able to be considered to be the *essentially* correct solution. It is only a model which may reflect the structure of a collective narrative agreed upon by the publics involved for the particular interaction being sought.

Therefore unlike some approaches to needs which define them according to supposedly fixed requirements of human nature, e.g. in 'Maslov's triangle' (see Fox 1990) the contextual relativity of what the publics consider are the pressing issues and necessities has to be taken onto account. Baudrillard (see Kellner 1989) points out that the distinction between needs and wants is arbitrary if there is any attempt to define them as universals. They are also always imprecise. But as addressed previously, a way to

transcend the dilemma is to recognise that rationality involved with learning is always contextual and contingent. Therefore as long as the definition of goals accounts for their vagueness and contingent nature they are not 'true and false' coercively ideological universals. A way to approach this is to define the concepts of the meta-values by possibility functions and fuzzy logic rules if they are compound (see Chapter 5 and Section 9.2). The use of GIS to help give visual display to help in the definition by individuals may help as well (see Section 9.2).

#### **9.1.2.1.1 Definition of needs.**

At present, in the Western countries involved in floodplain management, the generally held sufficient meta-values required to define needs are those discussed in Chapters 3 and 4 of: biodiversity, sustainability, and practicality (see Chapter 10). Included in these are the recognition of how all stakeholders are given equal allowance to be involved in defining the issues, and to be listened to. They can be summed up as referring to a commitment to functional and reflexive social structure reconstructed according to moral freedom. As also mentioned in previous Chapters 3 and 4 a methodology that can allow this process to occur is a development of SSM. The definition of an appropriate decision rule of social rationality to define needs is then an expression of the definition of a consensually decided upon conceptual model which can be carried out through use of fuzzy logic with GIS to interface with the publics.

#### **9.1.2.1.2 Needs/wants matrix.**

The distinction between needs and wants can be juxtapositioned with the three spheres discussed in Chapters 4, 5 and 6) The result is a matrix (see Figure 9.2). Here the approach by Rawls to use an averaging rule of some type for the definition of utility values for each level is carried out in sphere 1 situations as this is where the independence axiom is defined as applicable. In sphere 2 situations where the independence axiom does not apply, and trust and cooperation to form functionally interactive wholes is required, an 'and' (conjunction of some type) operation is required instead of independence, as the missing of a component fails the whole system, or at least puts strain on it beyond the arithmetic proportion an averaging analysis would determine. The whole may be sensitive to small changes of crucial components beyond thresholds even with relationships of trust in place.

In sphere 3 there is not agreement and so adherence to any goal level is not possible. But as mentioned above, the issues arising in sphere 3 are what help define the

	sphere 1	sphere 2	sphere 3
needs	a	b	
wants 1	c1	d1	
wants 2	c2	d2	
⋮	⋮	⋮	

**Figure 9.2;** Needs/wants matrix.

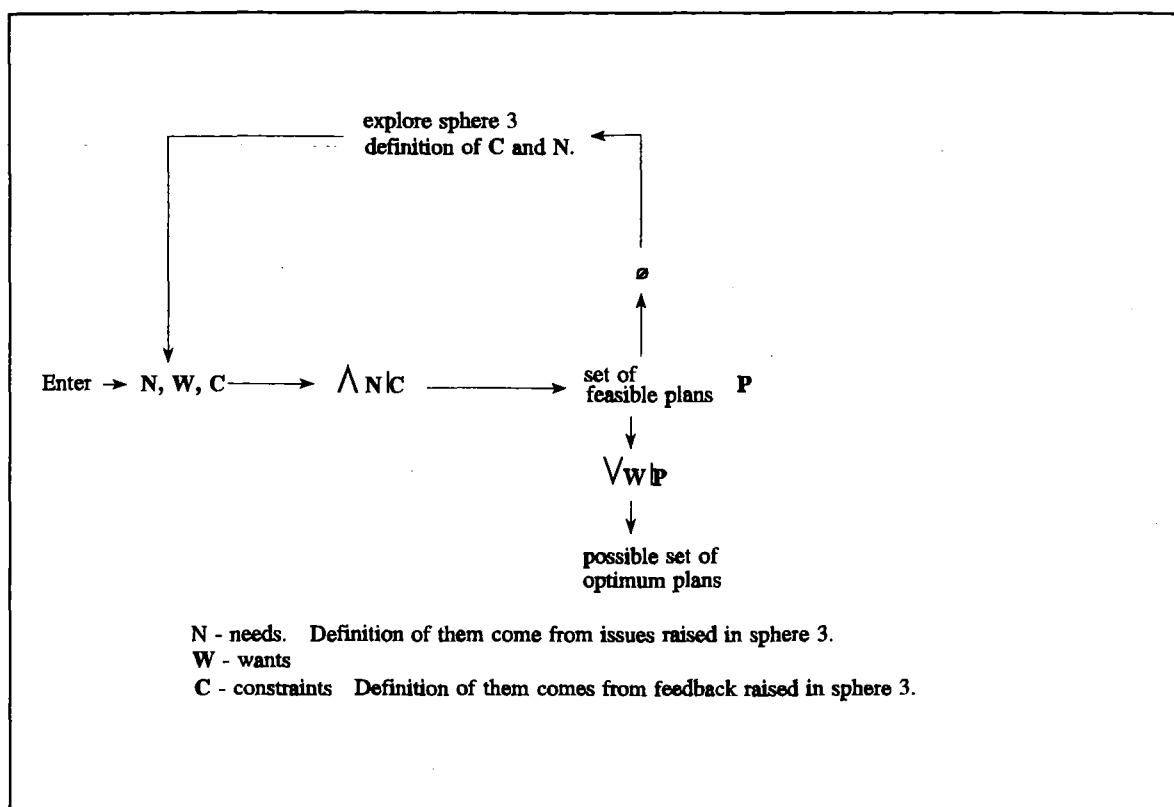
meta-values that are able to define what are needs. So sphere 3 still has a part to play in the decision process. The algorithm in its most simple form is then given by Figure 9.3.

In the algorithm, the difference between needs and wants is given by how sphere 1 needs form part of a whole in a sphere 2 situation, i.e. the fulfilment of needs are a goal or sub-end necessary to allow the whole to be maintained alongside the other parts. Whereas sphere 1 wants are not necessarily related to sphere 2 wants. If this distinction is made then technocratism (including the welfare function type definition of social rationality) is avoided as wants can not form an un-integrated whole growing out of context and thus producing Ellul's technological system (cancer). If this distinction is made then the present troublesome totalizing discourses of modernity, including neo-classical economics, can be avoided because second-order feedback stemming from sphere 3 is explicitly incorporated.

### 9.1.3 Expert system (ES) methods.

Expert systems (ES) attempt to model how people actually make decisions. The aim is to develop models of the decision-making capability of humans in ways that allow computers to aid in decision-making. They potentially have the capability to help





**Figure 9.3;** Recursive algorithm.

reflexivity and conversation. The emphasis has been in the development of how people use rules as types of heuristics, and how people are able to handle uncertainty and precision in complex ways by doing so. Therefore to the extent complex, vague and qualitative understanding can be defined as sets of rules the use of ESs can extend the scope of human decision-making through the use of computers. The use of rules is the most general way that aggregation was defined in Section 9.1 and therefore also provides the most flexible way to approach the issue of modelling dependencies.

The agenda of ESs as it has been taken up by this research is similar to that of SSM except that there is the explicit aim to develop modelling using computers to help in the methodology. This may or may not be a help. But there are arguments that under certain situations computerisation of such qualitative tasks can/could be of benefit. Basden (1983) argues that this occurs when there are between approximately 10 and  $10^4$  rules to consider. As found later in this chapter a reconstructed methodology for floodplain management using ESs falls within this category.

The theory relied upon in ESs comes from artificial intelligence (AI) as that is where there is the attempt to model human intelligence. An area of AI research which has been particularly useful for the development of an Expert System which can be helpful

for the soft system involved, is that of conversation theory (Coombs and Alty 1984). The theory was initiated by Pask (1975).

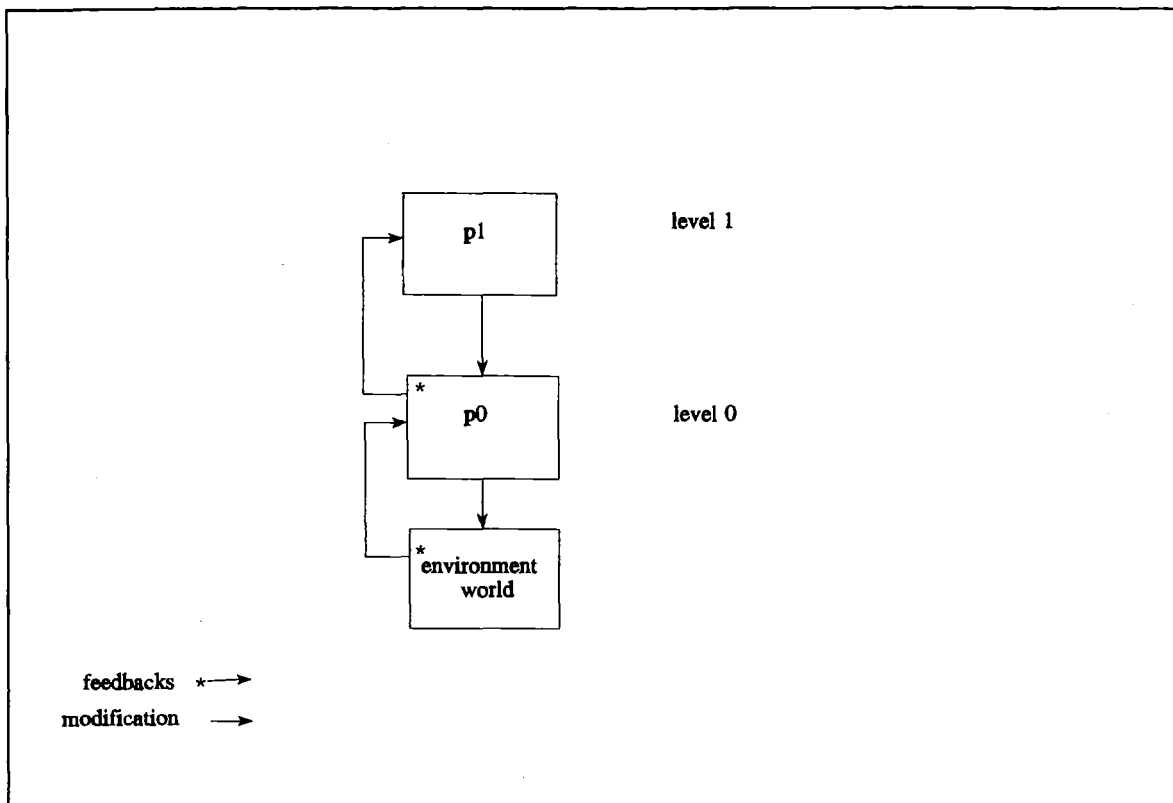
The basis for the approach developed by Pask was to assume that a system was defined with no external reference, i.e. a non-rationally created distinction. As developed in Chapter 4 it is often referred to by those concerned with systems methodology (e.g. Wilden 1980, Elms 1989; and Gaines and Shaw 1987) and produces a coherent approach compatible with the phenomenology, postmodern theories, and also that of fuzzy logic based on intuitionist mathematical philosophy. Thus it provides a basis for a non-behavioural decision theory (see Chapter 5).

What Pask did in the development of communication theory was to consider the interactions between two subjects who perceive systems in this way, i.e. modelling a dialogue. What Pask discovered was that the interactions can be modelled by the creative reconstruction of the system which occurs through the interaction of the two subjects in conversation as a recursive process. It provides a theory and set of models from artificial intelligence (AI) which are useful in the development of expert systems. Coombs and Alty (1984) developed a model of the theory for application in ESs. More recently it has made an impact on the development of 'machine learning' (see Section 9.1.3.2.2).

#### **9.1.3.1 Communication Theory.**

The simplest component of the process of conversation is shown in Figure 9.4 (after Coombs and Alty 1984; Figure 1). This component refers to how a perception changes (or how rules or procedures change in an ES) in reference to constraints.  $p_0$  is the system perception.  $p_0$  is the consciousness or the world that is a construction of both perceptions and mental concepts.  $p_1$  is the meta-perception, 'worldview', core culture or cultural ideology (meta-rules and ideals) which frames how the perception is and can be made.  $p_1$  is a constraint given by the language game, yet which is also the created abstraction of  $p_0$ , hence the feedback modelled in the hermeneutic circle (see Chapter 4). The world or environment refers to the other spheres of reality which also provide constraints (physical, biological, spiritual/transcendental).

What is not explicitly mentioned in Pask's theory is how the transcendental sphere 3 nurtures how the interactions produce a creative development of  $p_0$  in a way which is an improvement as well as acting as a constraint. In other words, how the resulting core culture ( $p_1$ ) becomes coherent and directing activity so that social life is appropriately adapted. Never-the-less this dynamic is assumed by Pask (1975) in his valuing of the communication process as an epistemology. Therefore the transcendental system is



**Figure 9.4;** Model of perception.

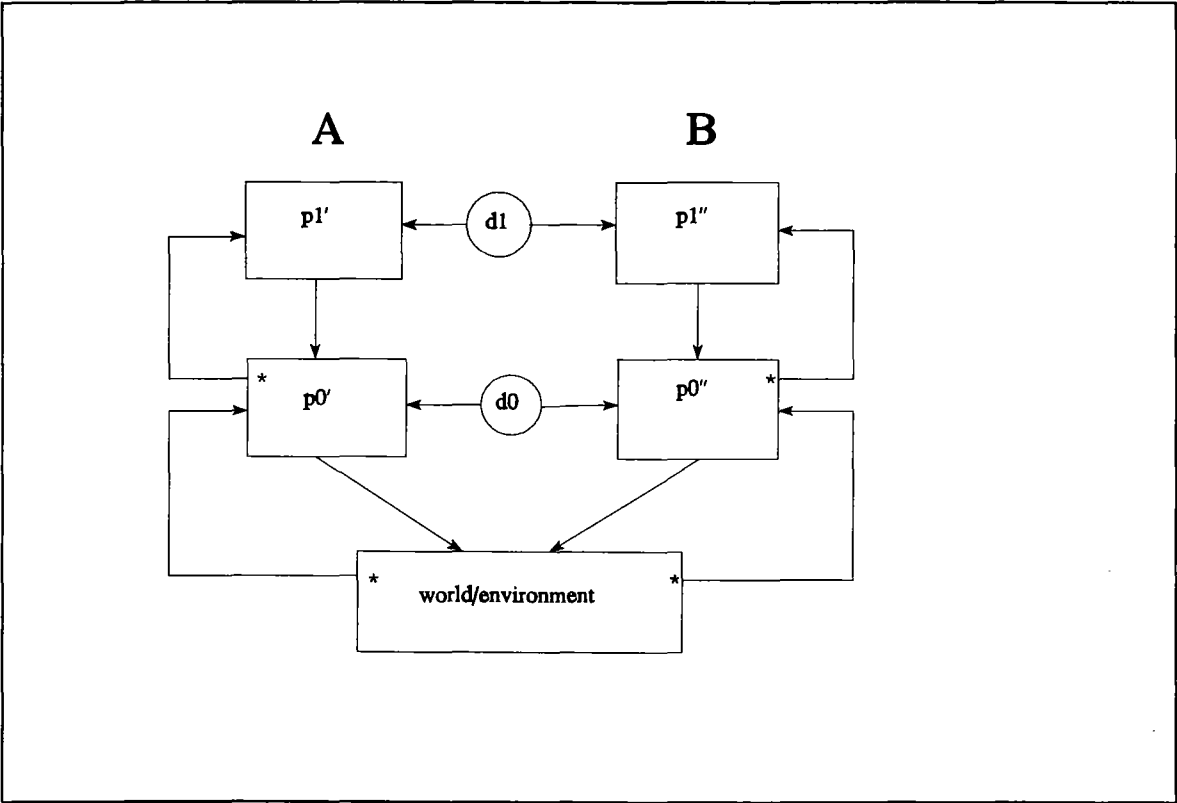
implicitly included in Pask's approach. So the approach by Pask is consonant with that of the reflexive spheres developed in Chapter 4, and especially with Heidegger's; where Being is present in all the presencing of the different spheres of reality and their interactions.

A few points can be made. The p0s can be considered to be individual in a particular context. However the p1s are considered to be more universal and existing as the basis for a culture, i.e. they refer to the level higher in the hierarchy of interbeing to be integrated within. In the postmodern theory developed in Chapters 3 and 4, and as already mentioned, these 'universals' are recognised as only contingently universal and the construction of 'universality', or in other words meta-values or 'truth', has a social role to legitimate a certain cultural adaptation to a particular ecological context. But for the context at that stage of co-evolution, they should be considered to be universal with meta-views defining a core culture nurturing appropriate system perception. P1 have to be defined in a way that is open to change as co-evolution proceeds through change in particular perceptions and constraints, i.e to carry out hermeneutic circle dynamics. The non-naturalistic approach developed adds that an undefinable universality (the sacred or grace) 'inspires' contingent and relative universals so that they work in context to an

extent. As also mentioned above this is how dialogue is able to be rationalized as working. In conversation grace enters into the situation so the reconstructed system that emerges is a better one. Communication theory provides a framework with which to describe the dynamics as an ES.

Because general application is the main emphasis in the development of expert system methodology in this research, the development of the p1s has been emphasised. p0s are only referred to in case study material to develop the argument although general p0s that apply to floodplain management in countries such as Aotearoa/New Zealand are also developed in Chapter 10. What has been focused on are the appropriate ‘universals’ needing to be defined in the present postmodern state of floodplain development.

When conversation occurs, two of these basic components interact (see Figure 9.5,



**Figure 9.5;** Model of conversation.

after Coombs and Alty (1984); Figure 2). The result is a communication or dialogue between the two systems A and B; both co-evolving within the same environment. A new entity in the flux exists: the dialogue. In light of the above interpretation, the dialogue (language game) emerges through creativity inspired by grace and takes form in co-evolution with the environment.

There are three phases at the two levels. d is the old sets of rules. p' is the

newly built procedures.  $p''$  is the procedure building procedures. In the case illustrated in Figure 9.5, B is 'inspiring' A. This can be reversed so that dialogue is modelled. The undefinable sacred (and systemic reflexivity) operates through the reciprocal juxtapositioning. Coombs and Alty (1984) emphasize that the process is a cooperative one. It is systemic reflexivity individuated (see Chapter 3 and 4). In terms of game theory it is in the direction of bargaining, but it has a more developed model of how the cooperation occurs. It is firmly within the phenomenological rather than the behaviourist tradition.

The interaction produces the dynamic which produces the development of perception, or what can be called reflexive learning. The conversation process models both the reflexive mulling over (meditation) by an individual as well as the dialogue between two individuals or groups and hence both analysis by professionals (as leaders) and the public participation process, and potentially conversation with non-humans for ecosystem integration as well.

Most importantly however this development in AI and expert systems enables the modelling of dialogue between disciplines, thus giving rise to inter-disciplinary research and development. This is significant because it means that the real issue is not the technical development of any particular framework according to a specific discourse and institution, but rather the intuitive creative process transcending all intellectual frameworks, worldviews and cultures. It points to a reflexive openness to the sacred or unknowing which produces wisdom, because trust and care rather than mere legalistic and/or dogmatic following of rules and discourse is carried out. If the postmodern position developed in previous chapters is correct this multi/inter-disciplinary activity is what is required by social institutions and needs to be quickly implemented into Western ones.

The interactions defined by Pask's (1975) theory are consistent with the definition of the feedbacks which Argyris (1982 and 1988) has developed as a theory of two-loop learning requires (see Figure 4.4) But, Argyris (1988) only allows a behaviourist interpretation by insisting that the guiding variables have to be deduced from observation of the manifest actions. So the two levels defined ( $p_0$  and  $p_1$ ) by communication theory which define the structure of the situation are not included in Argyris' model. This is a limitation because the structure is necessary to be known for the dependencies to be modelled and the systemic reflexive processes to be appreciated. SSM in taking a phenomenological approach however allows the structure to be incorporated into it.

The same conclusion reached in Section 9.1.1 is made: a behaviourist approach is incomplete and cannot explore the dynamics of cultural change and social adaptation.

### 9.1.3.2 Guidance expert systems (GES).

Coombs and Alty's (1984) application of Pask's theory in Expert Systems results in the development of 'learning expert systems' or 'guidance expert systems' (GES). As already mentioned this has led on to further development as machine learning. Coombs and Alty define some terms which serve as the basis for their ES conceptual analysis (discourse). They form the basic structure of the ES and so it is helpful to outline them and interpret them in terms of previous discussion.

A *conversation* is a creative process (reflexivity and dialogue) concerning a *topic*. A *topic* is defined by a set of assertions (rules and facts modelled according to MVL in this research). *Topics* form hierarchies termed *entailment nets*. In this research these have the hierarchical structure already explored. A *concept* fulfils a *topic*. This refers to a technical achievement according to a particular intellectual framework. It is what Checkland (1981) terms a 'how' (see Chapter 4). They are what are defined in sphere 1 according to Ravetz' analysis (see Chapter 5).

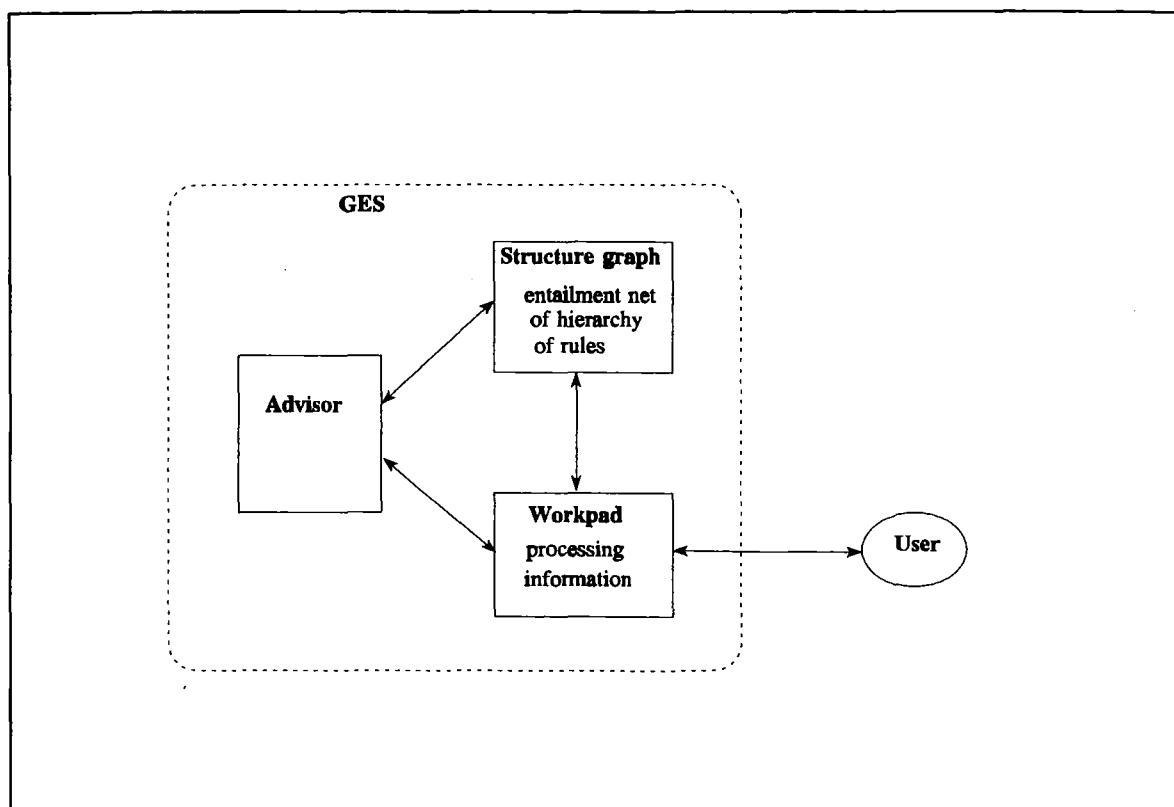
*Memory* refers to rules which operationalize *concepts*.

*Understanding* involves meta-procedures and can provide *explanations* of 'why' (in Checkland's terminology - see Chapter 4) the 0-level building of systems is carried out. This process is what is required to structure sphere 2 situations of cooperation and trust (see Chapter 5). It is what sphere 3 is concerned with. It has been found in previous chapters that the answer of 'why?' involves consideration of designed abstract systems involving ethics, based in a cultural vision, and is systemic reflexivity individuated. Therefore at best *understanding* involves wisdom and is therefore what produces coherent and appropriate culture.

Coombs and Alty's terminology is postmodern in that *concepts* are considered to be merely technical in terms of a particular discourse, and that understanding and wisdom is considered to be beyond conceptualization though able to be given partial and contingent explanations.

The aim of this type of ES is to produce *guidance* or *advice* presupposing creative, reflexive and lateral thinking. The *guidance* helps the others involved in the dialogue to learn. This is the use of power in an ethically legitimate way because it is used to nurture moral freedom and reflexivity rather than decrease or limit it (see Chapter 3).

Coombs and Alty (1984) have also developed what such an ES would involve. There are four components: 'user', 'structure graph', 'workpad' and 'advisor' (see Figure 9.6, after Coombs and Alty (1984); Figure 3). The 'user' in using the GES enters into a dialogue. The GES is an attempt to facilitate the learning of the user; i.e. all the other



**Figure 9.6;** Guidance Expert System.

groups and individuals concerned with discussing the topic. But in doing so they learn as well. So when the GES is fully expressed in algorithms it is an example of machine learning. To the extent the use of computers can be involved in this, is the extent that computers can be used constructively as part of the SSM process.

The 'structure graph' contains the entailment net or hierarchy of values. The 'workpad' has 3 features which form the structure of the model for the 'user' to converse with. These are the *current solution*, the *proposed solution* and *criticism of the user explanation*.

The *current solution* is the entailment net of topics given by existing facts and rules. The facts may be required results expected from the implementation of the rules, e.g. desired goals for maximum risk levels for flooding at a particular position. The *proposed solution* is what the ES of rules infer the expected results held in the facts to be. *Criticism of the user explanation* occurs if the *current solution* and the *proposed solution* are too different.

The comparison of the *current solution* and the *proposed solution* can be operationalised through the use of fuzzy set theory comparing possibility functions with the compatibility function (see Chapter 5), e.g. as developed in Chapter 7 when considering

truthfulness of hydrological models, and in the ES outlined in Chapter 8. The result is a measure of compatibility or truth value as to whether or not the *current solution* is adequate or not. In terms of the process of dialogue, the comparison of the current solution and the proposed solution is hypothesis testing through critical evaluation by others. If the truth value is too low then *criticism of the user explanation* occurs.

If there is *criticism of the user explanation* because a mismatch occurs between the current and proposed solutions, the 'advisor' is used. The 'advisor' has two roles:

- (i) To consider the effect of changes in parameters.
- (ii) To consider changes in the entailment net.

The 'advisor' therefore involves meta-rules which define what changes are required given a certain mismatch result. Here for example it is required that meta-rules reflect the meta-values required for sustainability. But in keeping with the philosophy developed here the meta-rules are recognised as never being certain of being adequate. So the 'advisor' itself has to be open to critical evaluation. Thus role (ii) is split into two parts: change of the structure of the entailment according to predetermined rules for when *criticism of the user explanation* occurs, and change due to the creation of new rules.

#### **9.1.3.2.1 Guidance operations.**

Role (i) involves programmed change in the values and imprecision of values used according to rules making up the 'structure graph' to see whether or not, and what changes allow the resulting 'proposed solution' to adequately match the 'current solution'. This can serve as information to help in the process to decide upon a new 'proposed solution'. Note that it cannot make new 'proposed solutions' however because such suggestions are a result of sources of information which/who have to decide whether or not the potential solutions are acceptable or not.

Role (ii) type 1 involves rules determined in response to previously decided upon alternative structures (conceptual models) thus constructing a hierarchy of acceptable alternatives. It may be decided to analyze how all the alternatives work as 'proposed solutions' and then to use a meta-rule to choose which is the most appropriate. This meta-rule can itself be an expression of role (ii) type 1 or role (ii) type 2.

Role (ii) type 2 involves interaction outside of the algorithms. From the point of view of the 'advisor' it involves experimentation of hypotheses and creation of new hypotheses so as to determine what new rules making up the structure graph or deciding upon which one to choose are required. The guiding meta-rules are determined experimentally. Information gained from the use of role (i) can be used as input from the



machine in its experimentation or dialogue with the publics. This experimentation by the 'advisor' is a type of 'machine learning'. In terms of SSM however, the experimentation by the questioning and learning machine is incorporation of the views of the publics into the formulation of new conceptual models. A conversation (in Pask's sense) between the public (via 'the user') and the computer is modelled.

Thus the GES can be reflexive as an expression of 'eternal recurrence' with the creativity of change being carried out by the reflexivity of the individual humans in their meditations and conversation with others (GES 'advisors' as well as other humans) involved. The significance of this is important as it answers Ellul's (1980) criticism of computers that they are only instruments of the 'cancerous' technological system. Just as SSM can counter criticism of hard system analysis (HSA), the use of machine learning in a GES can develop the use of computers so that they are not merely carrying out HSAs in a technocratic way.

#### **9.1.3.2.2 Machine learning.**

Machine learning involves changing the structure of the set of rules in an ES through the use of meta-rules of some type. In the most simple case solutions which have to be found from certain input are 'remembered' and so the same calculations need not be carried out again. i.e. the machine learning increases efficiency.

The use of the machine learning required in a GES is however of a more sophisticated type. What is required is that the experimentation be directed by rules that direct the machine to listen to the replies from the publics. This requires a set of meta-meta-rules to incorporate the feedback (see Section 9.2).

## **9.2 A RECONSTRUCTIVE POSTMODERN SYNTHESIS**

This can be tackled by considering the development of SSM as outlined in Chapter 4. As such it is a decision theory that is an application of a GES incorporating machine learning. There are six aspects that need further development however before an appropriate GES can be outlined:

- (i) The role of a sense of purpose and use of intuition in individual reflexivity of professional engineer-managers so as to be creative in the attempt to fulfil ethical criteria through guiding the reconstruction of narratives or paradigms synthetic of conflicting ones.
- (ii) The institutional aspect of the systemic reflexivity of 'eternal recurrence'.
- (iii) The need for explicit recognition of uncertainty and imprecision so as to avoid

ideological simplification, and hence the development of appropriate mathematics.

(i) The use of the reflexive three-spheres imagery to help structure entailment nets.

(v) The constraints that the environment puts on the process.

(vi) How truth and trust can be handled in SSM.

All six aspects are developed below.

### **9.2.1 Ethics and a sense of purpose in decision-making.**

It has been argued previously that to explicitly include ethics into SSM requires openness to grace (the sacred or the wild) which leads to contingent intellectualisation and hence the overcoming of essentialization and naturalistic legitimation, i.e. knowledge is socially legitimated and called truth because of its ethical effect which is understood as hierarchical functional integration. Truth is then the set of ideas necessary at a time and place for a culture to socially construct reality and human nature in a way that is appropriate for a culture's' co-evolution with its environment and to nurture individual growth. The reconstruction of narratives is guided by the norms second-order feedback instills. The result is creative synthesis of different discourses and even the views of conflicting groups. In terms of SSM a CM that synthesizes different RDs is created, e.g. the reconstruction of economic theory given in Chapter 8.

#### **9.2.1.1 The role of the engineer-manager.**

The engineer managing the SSM process of decision-making is a person with responsibility to endeavour to insure that increased understanding is achieved so that the situation can be improved in accordance with the criteria of ethics and sustainability. To do this requires skills. There is a consensus in the literature about what is required to do this.

The first step is to recognise that a sense of over-riding purpose is important. This is why the research here had to begin by considering engineering ethics and criteria for evaluation of projects. For example Postman (1992; p63) argued that purpose is needed for the ability to discern information which will help and which will not:

'Technopoly is a form of cultural AIDS, which I here use as an acronym for Anti-Information Deficiency Syndrome. This is why it is possible to say almost anything without contradiction provided you begin your utterance with the words "A study has shown...." or "Scientists now tell us..." More important, it is why in

a Technopoly there can be no transcendent sense of purpose or meaning, no cultural coherence. Information is dangerous when it has no place to go, when there is no theory to which it applies, no pattern in which it fits, when there is no higher purpose that it serves.'

Similarly, Ellul (1980) and Hoittois (1987) make the same point in their arguments that the ends (over-riding purpose) need to be determined so as to avoid the 'cancerous' spread of the 'technological system'; where ends have been lost sight of and technical means have become de facto ends (see Chapter 4).

In terms of the reflexive spheres imagery, awareness of over-riding purpose involves the internalisation of sphere 3 by the individual (individuation) so as to discover sacredness and creativity out of chaos and conflict, thus allowing coherence to be created because the conflict is seen in its full context. Wisdom is then gained to give feedback which is appropriate to stop the unbalance (spread of the 'cancer'). The point being made here is that the cancer can be stopped by individual wisdom rather than by further conflict acting as 'surgery' within the eternal recurrence of systemic reflexivity. Rather individual *wisdom* can transform the imbalance so as to maintain the good that technology and modernity have.

Postman's argument agrees with Ravetz (1990) and the postmodern tradition that ignorance as well as knowledge can be produced from information. Postman's view also however begins to outline what is required of information when it is to be knowledge rather than ignorance. As well as arguing that information requires to have a 'transcendent purpose' he also points out the needs for coherence.

It is argued throughout this research that these two aspects are the dimensions of wisdom gained through creative reflexivity involving non-rational intuition. Senge (1990; p 211) has described this as self-mastery which involves 'visions' of what is the potential which can be worked toward and so gives meaning to activity:

'(P)ersonal mastery is that people have an innate sense of purpose and that, when people reflect on what they truly want, most discover that aspects of their vision concern their families, their communities, their organisations, and for some their world. These are still "personal visions" in the sense that they emanate from an individual, but they reach far beyond the individual's self-interest in the narrow sense.'

Reflection and creativity involve the use of tacit knowledge beyond technical knowledge and involve reflexive concern for the context of decisions which involves caring for others than oneself, i.e openness to sphere 3 and its political milieu of concerns and issues.

Isenberg (1988) argues similarly that effective senior managers are able to critically carry out both analytical activities of rationality and be concerned with overriding goals and purpose at the same time. Isenberg continues that they create effective organizational processes and focus on and deal with a few general overriding goals. This can involve a simplifying process which involves multi-disciplinary interaction between experts which have concerns delegated to them, i.e. sphere 2 functional integration into a coherent whole, as an example of a multi-disciplinary and multicultural system reconstruction. Finally, that effective senior managers are able to critically carry out these two activities is to use *intuition* and *synergy*.

Synergy is defined as synthesis of isolated bits of data and experience into a coherent picture. Isenberg (1988; p531) describes it as:

‘A third function of intuition is to synthesize isolated bits of data and experience into an integrated picture, often in an "aha!" experience. In the words of one senior manager: "Synergy is always non-rational because it takes you beyond the mere sum of the parts. It is a non-rational, non-logical thinking perspective."’

This process of synergy is what is needed in the creation of root definitions and conceptual models in the SSM process. The "aha" experience referred to is from an analysis carried out by Koestler (1964) on how different types of knowledge are gained and equates to that given by de Bono (1990 and 1993) describing how the brain as a self-organizing system creates different paradigms that are discontinuous and are first experienced as insight and humour. However for Isenberg, intuition, as well as involving the integrating function to produce coherent pictures which is recognised as required for wise decision-making, is analyzed as being used in four other ways as well.

1. It is used in a way that professionals do and need to pro-actively use tacit knowledge (see Schon 1983). In the words of Isenberg (1988; p530):

‘Managers rely on intuition to perform well-learned behaviour patterns rapidly. Early on, managerial action needs to be thought through carefully. Once the manager is "fluent" at performance, however, and the behaviour is programmed, executives can execute programs without conscious effort.’

2. It is used to sense when a problem exists and what it is. This is necessary when engaged in the definition of what the actors are in the establishment of an SSM process.
3. It is used as a check on the results of a rational analysis. This aspect is what Ravetz (1990) argues is necessary to know when information is creating ignorance rather than knowledge. Its use here is to make sure that the uncertainty present is recognised and so counter-productive results do not occur.
4. It is used to bypass more formal analysis so as to move rapidly with plausible solutions which can later be checked.

Isenberg's analysis shows how professional involvement with sphere 3 occurs as a means for the professional to appreciate and guide the SSM process of the public's involvement. Integration of the conflict is aided by intuiting grace or the holistic context within it (see Chapters 3 and 4). However it also synthesizes the activities carried out in spheres 1 and 2. The professional's intuition is nurtured and used through 'keeping up' and transcending in wisdom, the dialogue between actors, especially political rhetoric needing to be deconstructed.

A consequence of the use of intuition in the conceptual modelling of the situation within SSM is that the process of education carried out in the learning process of dialogue does not involve mere addition of discrete bits of information. Rather, as Postman argues, it requires the need to be able to simplify the information with discernment so that a coherent picture exists. However this cannot be done so as to cover up uncertainty present and produce a self-fulfilling prophecy that is coercively ideological. Rather it is a synthetic and integrative process which reflects the holism (grace) inherently present. This can be used to produce an entailment net for use in a GES within SSM which is coherent and adequately comprehensive.

### **9.2.2 Mediation and planning.**

The seeing of political conflict and the chaos of sphere 3 situations as creative and with the potential for opportunities is a perspective shared with mediation theory (e.g Pavelka 1992).

Mediation can be interpreted as aiming to guide the systemic reflexive process of 'eternal recurrence' in the attempt to guide the process of getting something good out of conflict so as to bring needed change. Section 9.2.1 suggests that professionals who reflexively intuit the conflict process giving a sense of overriding purpose to it effectively use a mediatory approach to the conflict between stakeholders and actors. It has been argued that this is helped by multi-disciplinary management which can span the differences

in functional rationality. But as this widening of understanding is never perfect there is also the expectation that the various actors and stakeholders involved in conflict will be listened to on their own terms so that further understanding can be gained. This puts the issue back onto the manager-mediator who has to help open a world that enables this respect of different views to be instituted.

Blackford and Matunga (1994) point out however that mediation is only successful in producing ethical results if the voices have somewhere near equal speaking rights. Therefore engineer-manager-mediators need to appreciate the political context of existing injustice and so exhibit affirmative action, even involving sacrifice, to be advocates for the groups needing to have their voices heard. This is particularly relevant when considering statutory directives on engineer-managers. It may be necessary to do more than the law requires so as to be just and also effective (see Section 9.2.5).

Underwood (1991) makes the relevant point that over-riding concerns (turned into an overriding sense of purpose) need to be recognised as having a place in planning. She suggests a synthesis between paternalism and democratic relativism. In other words, the use of mediation to be open to all information within situations of conflict has to be coupled with responsibility towards technical and ethical principles based on wisdom gained.

Underwood concludes that what is needed is high quality analysis that recognises the appropriate domains of various analyses while maintaining a sense of overall coherence through it being linked to a sense of overriding concern. This is in agreement with the multi-disciplinary and inter-disciplinary approach developed by this research.

### **9.2.3 Theory for the vagueness of levels of abstraction.**

The analysis can begin by reference to the matrix McClennen (1981) used to describe the decision-making situation where uncertainty occurs (see Section 9.1 and Figure 9.1). The situation is distinct from that matrix if there is information present in the set of utilities which cannot be reduced to individual utilities. In such situations the alternatives have meaning as a whole and can be considered to be individual possible utility events, topics or facts -  $u_{ik}$ s in their own right. The alternatives  $A_i$  (the new  $u_{ik}$ s called say  $u_{ikl}$ ) can be considered to be a set of weighted focal elements of probability,  $E_i$ , on the domain of utilities  $u_{ik}$  of the new possible events (called say  $B_{kl}$ s)(see Chapter 5). Utilities  $u_{ikl}$  are compound in their makeup. Also the alternatives  $A_{il}$  are sets which have uncertain membership because it is not possible to determine the probability ascertained to the particular part of each  $A_i$  that each particular  $A_{il}$  includes. Rather, only possibility

and necessity measures can be given for the utilities  $u_{ik1}$  (see Equations 5.6 and 5.7). Hence the  $A_{i1}$  are fuzzy sets. Hence at a higher abstraction  $B_{k2}$  cannot form a partition and only possibility and necessity measures can be given. At this level of abstraction the utilities  $u_{ik2}$  are fuzzy and so the alternatives  $A_{i2}$  are compound fuzzy statements. Also objectives given by utilities  $u_{ik1}$  are not of equal importance because potentially different truth values can be given as  $B_{k2}$  do not form a partition. Thus there is a logical connection implied between them other than aggregation covered by utilitarianism and Rawlsian ordering.

For example in the situation illustrated in Section 9.1, the three possible events: subsidies for stopbanks, floodproofing and stopbanks, are not independent and do not form a partition because the components making up the three events are not elemental. There is some relationship between the decision to make stopbanks and the existence or not of subsidies for stopbanks, i.e a decision about whether to have stopbanks or not is dependent on whether or not subsidies for stopbanks are also offered. Hence it can be said in answer to the question whether or not to have stop banks that it is definitely necessarily true ( $N=1$ ) that the utility be equal to there being no subsidies and definitely possibly true ( $\Pi=1$ ) that it be equal to that where there are subsidies. Utilities in between these with have necessity and possibility values other than 1 or 0 and they will be dependent on what the elemental events are. What are elemental in this case are the rules and regulations involved and physical feasibility. The utilities of the three possible events are each fuzzy sets as analyzed in Chapter 8. Hence the actual utility values of the alternatives are not able to be defined from the information present unless logical statements being defined by the regulations and physical feasibility are expressed, as developed as rules in Chapter 8.

Higher level abstraction also exists; where the alternatives  $A_{i2}$  become the utilities  $u_{ik3}$ . Here the facts  $B_{k3}$  become imprecise as well as uncertain because the domain from which they are defined has become uncertain. For example, to continue with the above example, the fact describing the utility of a particular floodplain management plan gains pertinence only within a particular context. The context is the functionality of the plans - what the appropriate goals are in terms of integration at the systems levels of human community and ecosystem. Thus discussions of pertinence are carried out with fuzzy logic able to be given linguistic qualification.

The relationship between the levels adds insight into the dialectical relationship between imprecision and uncertainty. Imprecision is uncertainty aggregated at a higher level of abstraction. Also once imprecision and uncertainty are both present an infinite hierarchy of ever vaguer topics can be defined and related by ever fuzzier logic referring

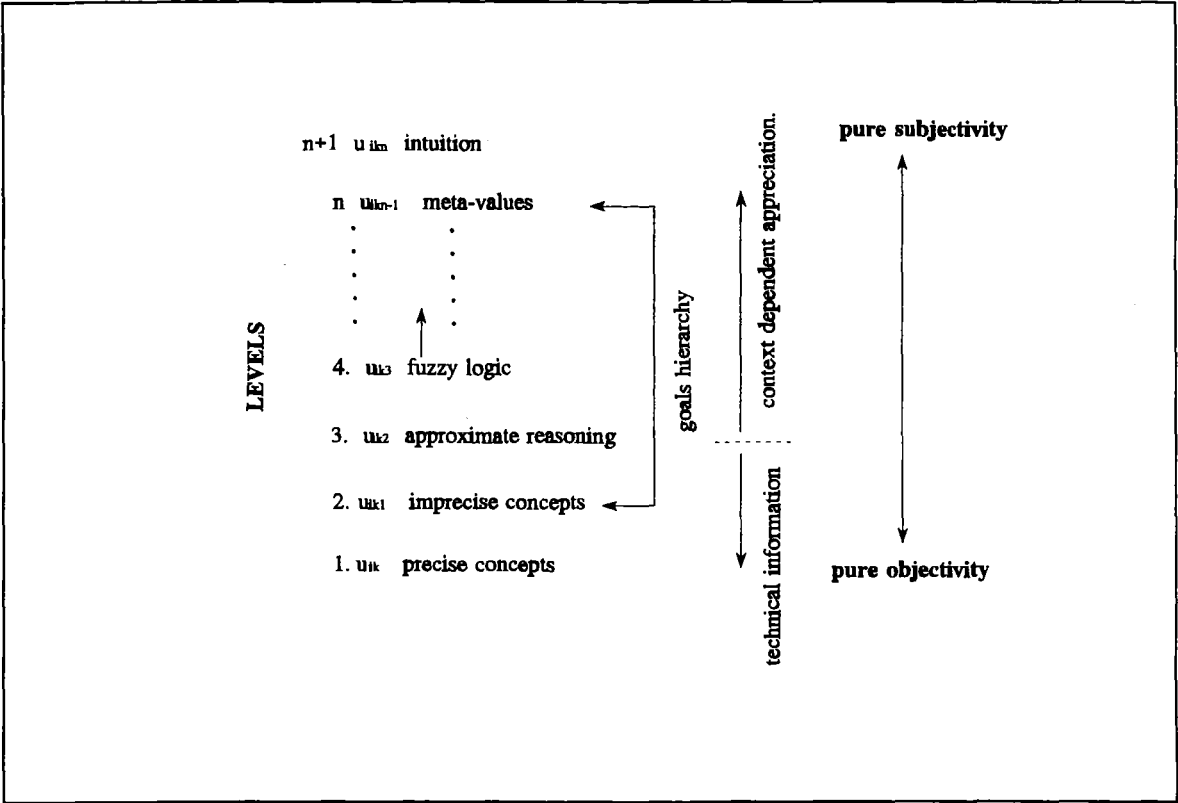
to levels of integration involving meta-ideals. This increasing vagueness in concepts when seeking coherence through abstraction is a recognised phenomenon, e.g. in intuitionist mathematical theory (Heyting 1971). Eventually some point may be reached where a unifying concept exists which gives an overall coherence to the set of concepts because any attempt to further create distinctions within it thus analysing at a higher level is just meaninglessly too vague, but at the same time is meaningless itself except as a symbol. This is equivalent to saying that such abstraction is paradox and dialectically points to an unknowing because paradox if represented logically is total vagueness (see Chapter 5). In other words, the context in which the concepts are useful as a language game is overreached and so are meaningless or at least obscure it, according to Wittgenstein and Heidegger respectively. Thus all knowledge is contextual as all unity is meaningless - there is no essential truth. To transcend particular contexts is openness to grace with direct insight to discern what paradigms of thought are appropriate, hence allowing the wise direction of reconstruction. The unifying concept is intuition and is what within any particular paradigm makes it true.

Some traditions use paradox at higher levels so as to point out the limit of knowledge and the need for wisdom. The use of mythic metaphor and juxtapositioning of mixed metaphor does this. As also already mentioned, the use of literature is the most common form with which to produce this reflexive process of personal relating. If it is carried out to structure decision-making, the hope is that a core culture that is not dogmatic and is reflexive enough to allow adaptation without loss of coherence is nurtured. It would be expected to be good humoured and peaceful even if lively in debate (de Bono 1990).

Levels of abstraction which occur are given by Figure 9.7. The absence of classical deterministic events can be explained in terms of the systems theory. Deterministic events according to transcendental realism are special cases of physical systems which are closed. Therefore they are by definition not empirically verifiable but only conjectured to occur at a level equivalent to  $u_{ik}$ . Any measurement of them is fuzzy and occurs at the level of  $u_{ikl}$ , e.g. the hydrological modelling developed in Chapter 7, which can be compared with goals. Goals occur from  $u_{ikl}$  and above. A hierarchy of goals are formed which forms an entailment net.

At one extreme there is pure objectification (logos as absence, to use Derrida's terms (see Lawson 1985)) as conjectured by classical deterministic and stochastic analyses, and at the other of  $u_{kn}$  there is extreme subjectification (presence void of content or logos). Vision synthesizes them, and wisdom transcends them. Tension occurs between them so





**Figure 9.7;** Logical levels of abstraction.

as to create a world expressing a 'will to power' constructing meaning and thus the systemic reflexivity.

**9.2.3.1 The construction of hierarchical sets of rules in a GES.**

Approximate reasoning and fuzzy logic can be used in the 'workpad' of a GES to test for the feasibility of possible conceptual models constructed as entailment nets of rules. This allows a comparison between the 'present solution' (one which would allow the entailment net to be accepted) and the deduced result from available data and the proposed rules of the conceptual model (CM), the 'proposed model'.

The result of the comparison is a compatibility function if the propositions are alternatives from level 4 or above, which can be normalised into a binary logic statement by Equations 5.16,17,24 and 25. Binary interpretation enables a decision to be made as to whether the CM is viable or not. If  $\Pi(F;A) = 1$  where F is the 'proposed solution', and A is the 'present solution', then it is acceptable. The binary result is one occurring at level 3. Thus this process allows 'proposed solutions' involving entailment net hierarchies involving levels 4 and above to be evaluated. A plausible set can be constructed to give a fact describing the plausible CMs. It has to be precise because a conceptual model is

used or it is not used. They cannot be vaguely implemented even if the truthfulness of them may be uncertain and imprecise. However compatibility functions can be used as part of a conditional result for ‘criticism of the user explanation’ higher up in the hierarchy of levels in the entailment net. This can be carried out with linguistic statements. This occurs when a rule is used to carry out comparison of viable CMs (see Section 9.2.7).

For levels below level 3, analyses can be transformed by defining the pertinence of each value. The defining of pertinence enables propositions occurring at levels 1 and 2 to be included into approximate reasoning, and so be part of the logic of the entailment net and part of the ‘criticism of the user explanation’ producing the plausible set of CMs. For example, the analysis carried out in Chapter 7 for flood warning.

This process of centring the analysis about the third level is practical and so appropriate for a GES, because decisions are usually made in a precise fashion as to what are viable CMs. This is not a logical requirement, but for the functionality of calculus it is required to limit the possible CMs (see Section 9.2.7). Comparison of plausible CMs involves going through the process again which also eventually returns to a level 3 binary decision as to what are the best CMs. Further comparison ultimately results in a binary decision about the optimum result.

### **9.2.3.2 Construction of conceptual models.**

As mentioned in Chapter 5, the representation of the systemic metaphor in a SSM process can be by compound fuzzy statements making up an ES of fuzzy logic algorithms. Thus because a SSM is an iterative process, development of the fuzzy logic algorithms is an iterative process also, which may produce a form which every ‘actor’ can accept as appreciating the situation at issue.

Postmodern approaches developed here argue that the engineer-manager has a responsibility to maintain the substance of the algorithm so that it reflects ethical and physical reality, i.e. so that technical information and professional responsibility are not compromised, which requires wisdom! In other words the engineer-manager has to maintain a coherent structure through perceiving an overriding purpose. To do this they need to use literature to reflexively engage the listeners. No decision-making theory can be appealed to! However hierarchical decision-making theory can be used to help structure the entailment of goals.

### **9.2.4 Features of the reflexive spheres.**

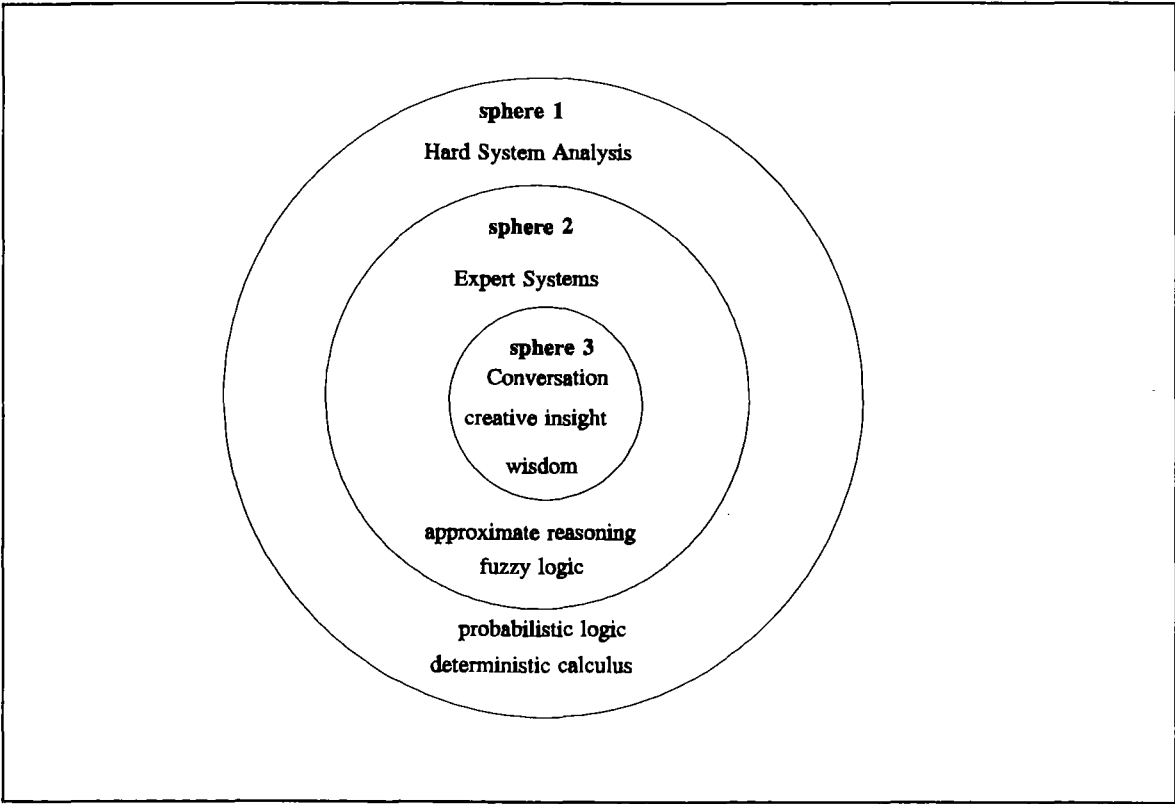
The use of the reflexive spheres imagery clarifies both the complexity present and

the hierarchy of concern in decision making. They can be used to give structure to the entailment net of a GES. Sphere 3 is the context in which the activity occurs and is present in the dialogue of the ‘advisor’ with the ‘users’.

In sphere 2 where coherence is possible and so a feasible reconstruction can occur, the process of decision-making involves nesting hard systems analyses (occurring in sphere 1) within the overall SSM process, and nesting specific technical analyses within the hard system analyses.

In sphere 1, behavioural decision theory is appropriate as the community relationships and processes are stable enough that reconstruction is not required. However the behavioural theories used must model the existing systems otherwise they will act as reconstructions never-the-less but in a destructive way. Technical analyses are able to be carried out as long as the uncertainty is recognised. For example the hydrological analyses developed in Chapter 7.

Thus the definition of appropriate behavioural decision-making analyses, hard system analyses and Expert Systems form an entailment net in the Structure graph of a GES which integrates the levels of logical abstraction and the reflexive spheres (see Figure 9.8).



**Figure 9.8;** Integrative entailment net.

The change in focus in analysis from an outer or higher sphere to an inner or lower one refers to an increase in the degree of abstraction and scope of context being sought to be appreciated. The attempt to define a lower sphere situation involves a decrease in abstraction and hence decrease in vagueness in the attempt to clarify means to achieve goals being sought for any particular level of integration. An entailment net occurs for each level of integration being sought. As mentioned above, the overall focus and balancing point for the process is where decisions are made about viability. This occurs in sphere 2 where overall functional integration is achieved.

The definition of appropriate entailment nets allows for the appropriate implementation of technical subsystems and for the development of cooperative interaction between services and experts with trust between all groups. This represents individual reflexivity creating an opening to grace, sacredness or wildness and hence life with the immortal gods within interbeing (see Chapters 3 and 4).

**9.2.5 Constraints on the process.**

Forester (1985) working within the critical social science tradition has outlined what factors bound rationality. These can be interpreted as that which hinders the rational

	socially ad hoc	socially systematic-structural
inevitable distortions	<p>idiosyncratic personal traits affecting communication</p> <p>random noise</p> <p>1. Cognitive limits</p>	<p>information inequalities resulting from legitimated division of labour</p> <p>transmission-content losses across organisational boundaries</p> <p>2. Division of labour</p>
socially unnecessary distortions	<p>wilful unresponsiveness</p> <p>interpersonal deception</p> <p>bluffing</p> <p>3. Interpersonal manipulation</p>	<p>monopolistic distortions of exchange</p> <p>monopolistic creation of needs</p> <p>ideological rationalization of class or power structure</p> <p>4. Structural legitimation</p>

**Figure 9.9;** Causes of bounded rationality.

process of discourse within SSM in sphere 2. Even though the research here rejects the rationalism and perspectivism found in the critical social science tradition because it fails to appreciate the importance of the non-rational and reflexivity (including the reflexive interaction of the three spheres), Forester’s typology (Figure 9.9, after Forester 1985; Figure 4.1) is useful to take into account when considering how to institute a multi-disciplinary and multi-cultural forum.

Inter-personal manipulation occurring in socially ad hoc situations is what Argyris (1982 and 1988) outlines as occurring where there is social incoherence due to individual lack of integrity. This along with structural legitimation occurring to maintain incoherence is what postmodernism developed in Chapters 3 and 4 seeks to change through nurturing of individuals to have the integrity to express creatively as their truth the awareness of the sacred.

Forester (1985) also outlines possible appropriate responses to the bounds (see Figure 9.10, after Forester 1985; Figure 4.2). Remedies to inevitable ‘distortions’ are

	socially ad hoc	socially systematic-structural
inevitable distortions	risk analysis hedging allowing redundancy 1. Cognitive limits	boundary-spanning specialization of function socialization of risk 2. Division of labour
socially unnecessary distortions	bargaining checking and monitoring legal remedy 3. Interpersonal manipulation	community organizing coalition utilization exposure and critique of ideology 4. Structural legitimation

**Figure 9.10;** Appropriate responses to bounded rationality.

carried out in sphere 1 and 2 analyses, i.e. technical risk analysis and functional role integration. However they can also be expected to create them if they are essentialized and applied out of context. What is missing in Forrester’s analysis of inevitable distortion

is recognition of the need for the development of trust through relationships transcending knowledge and inevitable distortion. Postmodern interpretation is accepting of the inevitable 'distortion' because it is paradoxically the opening to the Sacred as well as being a pole creating the tension making up worlds (see Chapter 4). So it is seen as good if handled appropriately as it leads to ethical activities like trust, caring, and nurturing as well as knowledge. By comparison, critical social science, along with Forester, only sees it as inevitable limitation on the rationalist ideal of the Enlightenment to seek universally applicable rational principles.

Remedies suggested by Forester for unnecessary structural social distortions involve much of what is carried out in an SSM process of community involvement. Remedies to socially ad hoc unnecessary distortions involve activities carried out in technical analysis and dialogue sincerely facing uncertainty within a SSM. This includes legal remedies which can also be part of a SSM. In floodplain management in New Zealand at present (1995) legal remedies are an option because floodplain management is carried out by regional councils acting under a statute, the Resource Management Act (RMA). Plans produced are legally binding. However the use of law has inherent limitations (see Section 9.2.5.1).

A limitation of the typology is the failure to point out the inherent link between structural social distortions that are necessary and unnecessary. The postmodern view of self-fulfilling prophecies enables the link to be seen which helps to overcome both. Social integration provides social 'bottom lines' which must be recognised as the basis which creative mutation must be consistent with until the 'bottom lines' are changed. It is both a mistake to consider that 'bottom lines', e.g financial viability, are absolute as it is to consider that they do not have to be taken into account. To consider them absolute is to be constrained into denying second order feedback, and to not take them into account is to fail to be aware of the social construction occurring. 'Bottom lines' are institutional and usually legally enforced. Thus it is necessary to accept them contingently as necessary structural distortions when they are not working well. However through direct change of the rules of the institutions (which is possible in a democracy) or creative reconstruction working within the bounds enables changes to occur. Regional councils in Aotearoa/New Zealand are in the position of working under statute but forming plans that are themselves legal documents and so they can change the bottom lines to some extent.

#### **9.2.5.1 The use of law.**

Allot (1980) makes a distinction between law and ethics. Law is understood

descriptively and ethics normatively. He goes on to describe how law is attempted to be understood and applied in two ways:

- (i) as model-making which people can adopt or not.
- (ii) as means to try to enforce social transformation.

If the second approach is adopted it is only successful if compliance also occurs, which effectively means that law is also working as a model to be accepted. Musheno (1990) explores how law operates in practice and argues that it is seen as a force which it is easier to comply with than to not do so. Recognition of an inherent value in the law itself as serving a necessary social role is at best secondary. From this it can be suggested that law should be aimed to be used as model-making, representing the wish of people to change social activities toward ways that are considered better, and laws are a type of discipline willingly submitted to seeking this end, i.e. it is explicitly and reflexively recognized as social construction. Therefore law as a social tool is abused when it is an expression of attempted domination, rather than a societal decision by all of society to improve behaviour in directions that society as a whole has deemed necessary through expression of moral freedom. The need to separate the defining of laws from decision theories which use dictatorial aggregations is obvious. Also Dworkin (1981) laments that decision-making about what are appropriate laws has begun to be decided by the use of the criterion of efficiency defining non-inferior sets.

However law itself is not a necessary or appropriate tool for social change or social construction. Allot (1980) argues that they are only appropriate when a society is large. They have inherent limitations because they are exterior and institutional therefore should be avoided if possible. If possible it is better to rely on personally known and accepted norms that are accepted as personal responsibility, which can happen in small-scale societies. Laws are appropriate tools where rights are also an appropriate concern. At the community level of personal relationships of 'family' they are not appropriate (di Zerega 1995). This point is highly significant because personal responsibility is the result and aim of reflexive analysis and the gaining of wisdom. So even though an engineer-manager may have laws to work within they are also expected to transcend them if they are to use law effectively.

Another approach which Dworkin (1981) criticises, is to rely on market 'mechanisms' rather than laws. As mentioned in Chapter 8 this argument is contradictory as markets themselves are exterior institutions. More importantly the reliance on a market prevents actors from developing responsibility. So it is contended here that the best approach is to accept the need for the institution of laws, including markets where they are

appropriate, and to encourage responsibility by reflexive individuals transcending laws so as to try to fulfil the ethical intent and value behind them. Then laws can be used as effective models to counter arbitrary dictatorships expressing merely systemic reflexivity and can help make sure that all intrinsic values are respected. But for this to be fulfilled dialogue due to individual reflexivity must be a consequence as well as the initiator.

Therefore law as a social tool is abused if the distinction between law and ethics is obscured. It is then legalism. If this occurs it is an example of the collapsing of ends and means that Hottois (1987) argues against. It means that sphere 3 situations are obscured and instead of facing the potential creative situation where dialogue comes in to play, social integration according to existing rules is attempted to be enforced. Hardin (1990) even extends this criticism to 'overly optimistic faith' in common law with its ad hoc process, which is otherwise lauded as being open to the needs of social consciousness.

Another important feature of law is that it acts as a social ordering and not as an arbiter of what is true (or what is ethical). Legal controls on intellectual activity and expression are rightly attacked as oppressive. The co-evolutionary change of laws to creatively bring about social adaptation legitimates laws and not vice-versa.

The mechanism involved when law is abused is the non-precautionary enforcement of an necessary idealisation (laws are necessarily binary in decision) that masks uncertainty surrounding the decision-making and point trying to be made (Gawlak and Byrd 1987).

In general legalism is the use of law to impose an ideology socially constructing a language game to encourage people away from individual reflexivity to non-individuated systemic reflexivity. This is significant because engineer-managers if they are to achieve the gaining of a sense of overriding purpose can creatively reconstruct successful CMs must not be legalistic! Legalism can be interpreted as the default activity by engineer-managers (and others) when not wanting to face the complex and fuzzy area of the Human Activity System and ethics (see Chapters 3 and 4).

Therefore it is crucial that the development of regulations or legally binding plans (as carried out in flood plain management in Aotearoa/New Zealand under the RMA) be achieved in the same way any CM is sought to be successfully developed. Otherwise it is inherently dictatorial and inadequate, whether it is the law or not! Because of this some laws may have to be seen as constraints rather than tools, and the view voiced by Hipel and Dagnino (1988) accepted that bargaining (somewhat like that carried out in SSM) is superior and produces better results than the use of law and litigation accepted.



### **9.2.6 Truth and trust in SSM.**

Truth refers to the trustworthiness of the knowledge. The less precise the more trustworthy, however also very likely the less useful. But it needs to be remembered that as concepts become more abstract they become inherently more vague yet are still very useful.

As trust is important for sphere 2 situations of stable social organisation it means that the truth of the rules in the GES is also very important if the CMs are to be used for reconstruction. Idealizations which are precise but not very true are not helpful by giving an ideologically false sense of usefulness. So honest recognition of vagueness is important if information is going to be used in sphere 2 situations where decision rules are defined.

Pedigree is also important for trust and linked to being able to obtain an adequate level of truth. High pedigree translates as proof of trustworthiness. New technical ideas may have low pedigree at first and the onus is on the professionals involved to prove their trustworthiness. At first high pedigree craft ideas need to be respected as they engender trust even if they may be inefficient and lack effectiveness. The move toward greater efficiency and effectiveness has to occur at pace with the development of high pedigree for the knowledge to be appropriate and able to be socially defined as 'true'.

## **9.3 APPLICATION OF A GES FOR FLOODPLAIN MANAGEMENT**

Reflexivity occurs in relation to three system levels and so the process can be considered to be three meshed SSMs (see Chapter 4). They can be called  $SSM_1$ ,  $SSM_2$ , and  $SSM_3$ . They do not correspond exactly to the three levels for which integration is being sought (the individual, human community and ecosystem), but seek to achieve integrity at all these three levels through the process.

$SSM_1$  refers to the SSM process carried out in the gathering of information, which necessarily involves the constructing of what the problems are and hence what information is required, e.g. where heritage is an issue and what Maori iwi are concerned about. It is carried out at the community level of existing personal relationships of trust and community understanding.

$SSM_3$  refers to the SSM process carried out in the scoping of issues that are presently not adequately being addressed in floodplain management. It is carried out at the political level where social conflict may occur.

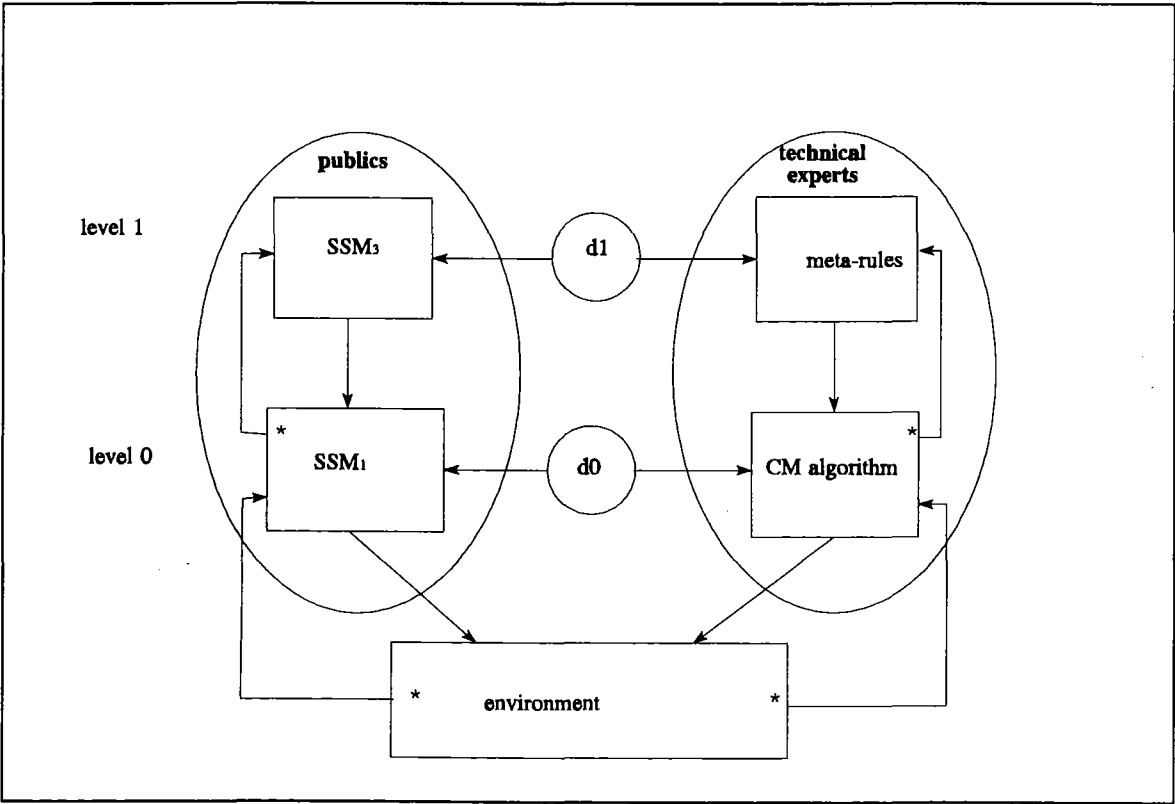
$SSM_2$  refers to the SSM process that seeks to construct management strategies. It is where the GES is involved. It integrates the various disciplines involved and hence

also the results from  $SSM_1$  and  $SSM_3$ . GES interacts with  $SSM_1$  and  $SSM_3$  in the process of machine learning. In terms of  $SSM_2$ ,  $SSM_1$  and  $SSM_3$  can be considered the 'real world' creating root definitions for  $SSM_2$  that form the basis for the creation of possible management strategies as CMs. It is because distinct discourses are involved in the three SSMs, that the CMs formed in  $SSM_1$  and  $SSM_2$  with/by the publics are perceived as 'real world' by the  $SSM_2$  process carried out by an inter-disciplinary team of technical experts and multi-disciplinary manager.  $SSM_2$  can be seen as the central process which integrates the whole process.

GES is how  $SSM_2$  is formalized so as to achieve functional integration at the three systems levels reflecting interbeing, as a learning system of adaptation, in the attempt to successfully co-evolve with the environment, i.e. to be sustainable by having non-traumatic cultural change while maintaining personal relationships of trust and care. It is what creates the CMs that become the social constructions creating history within the co-evolutionary process.

### 9.3.1 Synthesis of tools and analyses.

The communication model outlined in Section 9.1 is an appropriate basis with



**Figure 9.11;** Nested SSM.

which to consider how to synthesize the different groups involved in dialogue. This approach adds a more democratic perspective on the tri-SSM process outlined above. Placing the publics as the 'real world', and technical experts' inter-disciplinary team as that creating the systems analyses, makes a distinction between the two which privileges the technical experts to be the decision-makers. To avoid this a communication model can be employed so the two groups are seen as intrinsically equal voices in dialogue (see Figure 9.11).

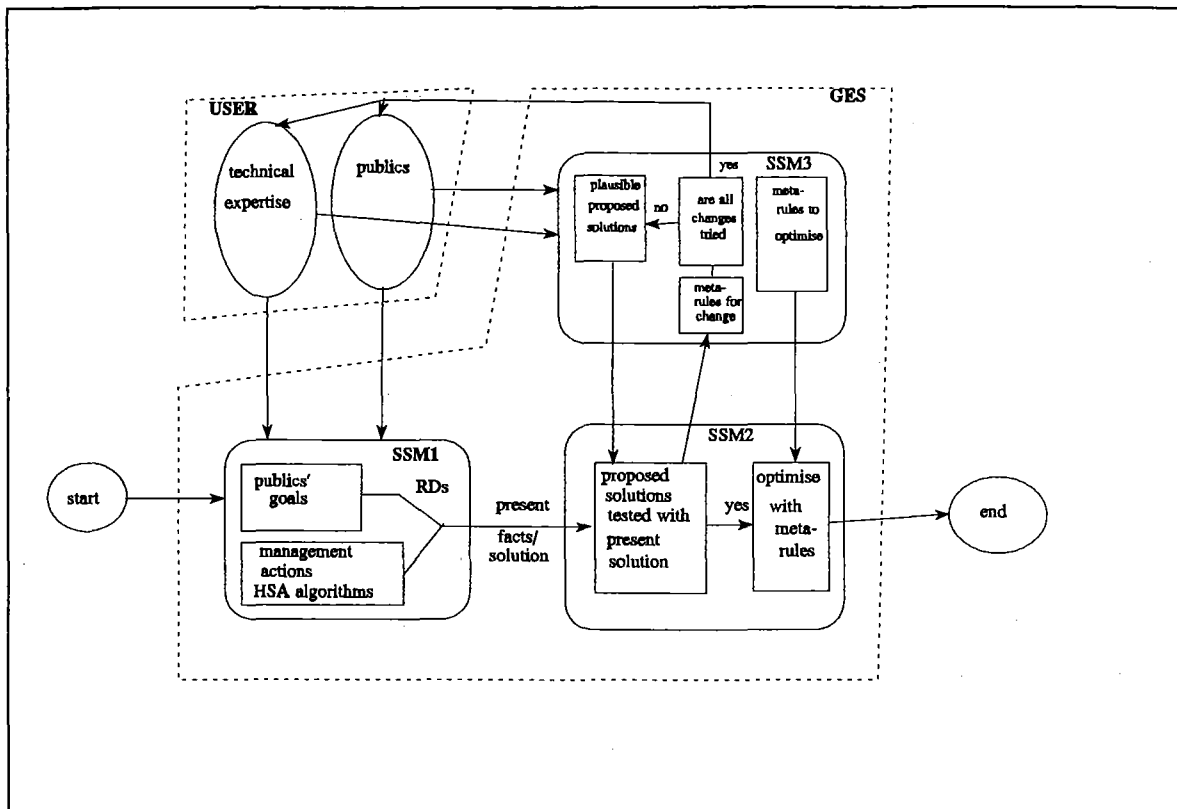
Level 1 operates as  $SSM_3$  for the public in the political realm with free voices able to express concerns so as to tell about inadequacies that exist in existing management. For the technical experts it operates as the application of meta-rules based on a coherent view of the whole process (a sense of overriding purpose). For the publics it is any public media and forum that exists. Ideally it should be institutionally incorporated. This would be consistent with the RMA for floodplain management in New Zealand (see Chapter 10).

Level 0 operates as  $SSM_1$  for the public as they express information about their worlds. For the technical experts it is expressed in the algorithms constructed for CMs.

$d_1$  is the process of forming CMs, including the use of veto according to meta-rules by the technical experts.  $d_0$  is the encoding and decoding of information so that it can be used within a GES. GIS can potentially be an important component for both encoding and decoding of technical knowledge. It can provide a meaningful interface between the publics and technical experts as the 'users' of the GES. Further it is where the main aspect of the entailment net occurs: all information that has a spatial reference. The use of GIS in a GES makes the information accessible for several discourses - for the publics and technical expertise.

The model outlined in Figure 9.11 is very complex in the technical sense given in Chapter 6. This is problematic because, as also mentioned in Chapter 6, the process involved with sphere 2 of risk management that has been linked to  $SSM_2$ , is required to be linear rather than complex in application for floodplain management. This is a consequence of the centralized authority that is necessary because a floodplain management plan is needed to be created and that it is tightly coupled through the existence of separate issues and concerns that are time-dependent.

The requirement for linearity can be achieved by turning the complex reflexive process into an infinite recursive sequence. It means that no final answer is achieved but because the process is one of SSM within eternal co-evolution this is not a limitation. Figure 9.12 outlines a linear process that enables the system in Figure 9.11 to be



**Figure 9.12;** Recursive nested SSMs.

operationalized. It is an application of Figure 9.3. This enables a hierarchical model to formulate a structure for goals to be incorporated. Needs and wants are defined in CMs with each having a hierarchy of concepts in an entailment net to formulate it. The integration of the entailment nets to form an algorithm for a GES with hierarchically defined goals is a process of determining the best CM according to meta-rules (see Section 9.3.2) below.

### 9.3.2 Algorithms for a GES.

A general algorithm to consider a general situation is given below. The social sphere is defined by hierarchies of goals (needs and wants), the physical and biological spheres by systems defined by hard systems incorporating uncertainty and imprecision, e.g. the hydrological system defined by the analyses given in Chapter 7. It is 'intelligent' in the sense of using machine learning to be efficient so as to not to recalculate already 'learnt' information.

1. Define systems and plausibility constraints.

The systems are defined spatially with boundaries for sub-systems being given by

the management actions that are to be considered. A sub-system is where one management option is decided. A management option can be a set of management actions treated as a single entity.

Plausibility constraints are constraints on possible management options. They can be defined so as to fulfil intangible and indirect needs (see Chapter 8).

2. For each of the  $m$  sub-systems define:

(a)  $n$  sets of realistic management options

$u_{jk}$ :  $j=1, \dots, n$ ;  $k=1, \dots, m$

A *realistic* management option is one which is technically feasible and also feasible in light of the goals. Logically  $n$  is infinite but in practice when considering wants so as to optimise plans, realistic limits can be drawn. However care must be taken to not arbitrarily limit possibilities. Possible options and acceptable definition of realistic bounds arise from the  $SSM_1$  and  $SSM_3$  processes.

(b) Fuzzy sets of cost for each management option  $\pi(C_{jk})$ . Cost can be taken to be a general term to refer to a value defined in terms of a goal that is a want rather than a need. In particular, monetary cost in relation to the goal of seeking cost effectiveness is important for floodplain management.

(c) Fuzzy values of  $c$  parameter values

$\pi(v_{ijk})$   $i=1, \dots, c$

Parameter values refer to values that management options produce in relation to needs.

(d) Goals (needs) in terms of fuzzy parameter values  $\Pi(g_{ijk})$ .

(e) Plausibility space of parameter values defined by goals. Plausibility values are not able to be defined absolutely. Ultimately they are required to reflect what can be consensually accepted to do so determined from within the  $SSM_3$  processes. What can be done to aid in this is the consistent and explicit use of a particular comparison of  $\pi(v_{ijk})$  and  $\pi(g_{ijk}) \forall i, j, k$ . For example in this algorithm there is the use of strict exceedance possibility (see Chapter 5).  $\pi(g_{ijk})$  are likely to be independent of  $j$  and  $k$ .

$$S(i, j, k) = 1 - (\pi(v_{ijk})^* > \pi(g_{ijk})^*) \quad \forall i, j, k \quad (9.15)$$

assuming that goals are maximum levels. If goals are minimum levels then  $\pi(v_{ijk})$  and  $\pi(g_{ijk})$  require to be interchanged.

(f) Plausibility space of management options.

$$Z(j, k) = 1 - \sup_i (S(i, j, k)) \quad \forall j, k \quad (9.16)$$

(g) Cost effective management option set ( $S_{jks}$ ) for each interval of effectiveness  $s$ .

$$u_{jk} \in S_{jks} \text{ when } \forall Z(j, k) = 1, (\pi(C_{jk})^*_s < \min^*(\pi(C_{jk})^*_s) > 0 \text{ where } \pi(C_{jk})_s = \pi(C_{jk}): \forall i$$

$$(\pi(v_{ijk})^* > \pi(h_{ik})^*_s) = 0 \quad (9.17)$$

and  $\pi(h_{ik})_s$  is the fuzzy definition of the effectiveness level  $s$ .

See Equation 5.23 for definition of global minimum.

When plausibility constraints are defined, management options which serve to fulfil wants other than the one associated with cost should be noted, and kept as cost-effective options (as members of  $S_{jks}$ ) for consideration when cost-effective options are determined for comparison of plausible options in terms of wants. They may be cost-effective ways to achieve the other wants.

$$(h) \text{ Cost of cost-effective management options is given by } \pi(C_{jke})_s = \vee \pi(C_{jk})_s : u_{jk} \in S_{jks} \quad (9.18)$$

Restricting options can make  $(C_{jke})$  more precise.  $SSM_1$  and  $SSM_3$  can be involved as 'experimentation' by the algorithm to determine what or whether restrictions are possible.

(i) Fuzzy parameter values for set of cost-effective management options

$$\pi(v_{ijke})_s = \vee \pi(v_{ijk})_s : u_{jk} \in S_{jks} \quad (9.19)$$

(j) A matrix of the inverse of marginal costs:

$$\partial v_{ijke} / \partial C_{jke} = p_{ijke} \quad \forall j, k \text{ where } \partial C_{jke} \text{ and } \partial v_{ijke} \text{ are fuzzy. Thus it is given by}$$

$$\Delta \pi(v_{ijke}) / \Delta \pi(C_{jke}) \text{ for each increment } s \text{ over the plausible space: } Z(j, k) = 1 \quad (9.20)$$

The inverse of marginal cost is required if goals define maximums thus allowing a precautionary approach to be taken. If goals define minimums then the marginal cost is required. All definitions of  $\Delta \pi(C_{jke})$  and  $\Delta \pi(v_{ijke})$  need to be carried out in such a way that it is absolutely true that an increment occurs, i.e. strict necessary exceedance = 1 (see equation 5.21). This is required to maintain isotonicity because possibility functions must be either positive or negative. They cannot be both. To carry out Equation 9.20 requires transformations to make it isotonic.

$$\text{let } \mu_*(C_{jke})_s = \mu(-(C_{jke})_s) \quad (9.21)$$

$$\text{and } \mu_*(v_{ijke})_s = \mu(-(v_{ijke})_s) \quad (9.22)$$

$$\text{gives } \mu((\Delta C_{jke})_s) = \mu((C_{jke})_{s+1}) + \mu_*(C_{jke})_s \quad (9.23)$$

$$\text{and } \mu((\Delta v_{ijke})_s) = \mu((v_{ijke})_{s+1}) + \mu_*(v_{ijke})_s \quad (9.24)$$

$$\text{also let } \mu_*(\Delta C_{jke})_s = \mu(1/(\Delta C_{jke})_s) \quad (9.25)$$

$$\text{thus giving } \mu(p_{ijke}) = \mu((\Delta v_{ijke})_s) \mu_*(\Delta C_{jke})_s \quad (9.26)$$

for any particular  $\alpha$ -level cut.

The calculation of inverse marginal costs enables the information calculated about cost-effectiveness to be 'remembered' so that when considering global solutions within a network necessarily requiring recalculation of values, repeated use of hard system analysis of technical systems (e.g hydrological routing) can be avoided.

Thus it increases efficiency.

3. Define system network of subsystems and control points where parameter values are analyzed.

4. For each 1st-order intersection point (x). Define a 1st-order intersection point as one which only includes sub-systems as inputs. A 2nd-order intersection is one which only includes 1st-order intersections. A 3rd-order is one which only includes 2nd-order and lower intersections and so on.

(a) Route parameter values according to technical system models, e.g. the hydrological system and so uses the results from Chapter 7.

(b) Determine the effect a particular input y has on parameter values at the intersection x,

$$\partial v_{ix} / \partial v_{ixy} = k_{ixy} \quad (9.27)$$

where  $\partial v_{ix}$  and  $\partial v_{ixy}$  are fuzzy thus giving a fuzzy  $k_{ixy}$ .

In 1st-order intersections  $\pi(v_{ixy})_s = \pi(v_{ijke})$  at the level s that corresponds to the effectiveness of the management option j. The same requirements and transformations used in 2(j) need to be applied to give  $\mu((k_{ixy})_s)$ .

(c) Determine the parameter values at intersections as a function of input values from subsystems:

$$\mu((\Delta v_{ix})_s) = \sum_Y \mu((\Delta v_{ixy})_s) \mu((k_{ixy})_s) \quad (9.28)$$

for any particular  $\alpha$ -level cut.

(d) If the intersection is a control point calculate the plausible cost-effective management option space:

$$Z_e(x, j, k) = 1 - \sup_i (\mu(\pi(v_{ij})^*) > \pi(g_{ix})^*) \quad (9.29)$$

where

$$\pi(v_{ij}) = \sum_i \mu(\Delta v_{ijk}) \mu((k_{ixy})_s) \quad (9.30)$$

and  $j$  corresponds to the appropriate  $y$  and  $s$ .  $g_{ix}$  is likely to be independent of  $x$ .

(e) Determine cost effective steps  $(\Delta C_{xe})_s$  for intersection  $x$ :

$$\pi((\Delta C_{xe})_s) = \sum_{y \in S_{cys}} \pi((\Delta C_{xy})_s) \quad (9.34)$$

Where in 1st-order intersections  $(\Delta C_{xy})_s = (\Delta C_{jke})_s$  where  $S_{cys}$  is given by  $y$ :

$$\forall i (\pi((p_{ijke})_s) \cdot (k_{ixy})^* < \min^*(\pi((p_{ijke})_s) \cdot (k_{ixy})) > 0 \quad (9.32).$$

Restricting options can make Equation (9.31) more precise and is where 'experimentation' through  $SSM_1$  can occur.

(f) Determine the inverse of marginal costs for intersections in terms of parameters.

$$\partial v_{ix} / \partial C_{xe} = p_{ix} \quad (9.33)$$

The solution of Equation 9.33 is analogous to the solution of Equation 9.20 and uses Equations 9.28 and 9.31. The solution are used for analysis of all higher order intersections.

5. Repeat procedure 4 for all 2nd-order intersections and then higher intersections until the network is completed. For 2nd-order intersections  $p_{ix}$  is analogous to  $p_{ijke}$  for 1st order. Routing of parameter values is carried out as in 1st-order analysis for all orders.

6. At all control points at 2nd-order intersections and in 2nd-order reaches (legs) determine the set of cost-effective management options to achieve the goals pertaining to each parameter. Then do so for all 3rd-order control points until all control points are analyzed. A plausible set of cost-effective management options  $Z_e(x,j,k)$  at any particular control point is constrained by all definitions of  $Z_e(x,j,k)$  that are 'upstream' of the control point.

7. Apply linguistic definition at all control points of the achievement of needs by the plausible global management options (see Chapter 5). The set of plausible global management options is given by  $Z_e(x,j,k)$  where  $x$  is at the 'confluence' of the network. The global set constrains the possibilities obtained at all control points within the network.

Possibility functions defining statements like 'it is very true that the goal defined by parameter  $j=3$  is achieved' can be synthesized.



8. Determine the globally (and sub-globally) most cost-effective set of management options. Sub-global is concerned with part of the system 'upstream' from any particular intersection. The global analysis is carried out by determining the cost-effective steps at the confluence intersection and then to proceed to follow 'upstream' the appropriate inputs and determining the most cost-effective step at lower order intersections. If  $S_{Cys}$  has more than one input for any particular intersection then no route 'upstream' can be preferred between the inputs in  $S_{Cys}$ . Therefore global (and sub-global) cost-effective sets of plausible management options can be determined for each incremental increase in effectiveness at any intersection. N.B. This method does not idealise the optimum. Uncertainty as to what is the optimum strategy at any effectiveness is fully taken into account as is also the imprecision as to the actual cost that the set of management options will entail.

9. Calculate the cost of each plausible global management option ( $\pi(C_o)$ ). Any particular set is the simple sum of the  $\pi(C_{jk})$  for each management option at each subsystem.

10. Apply decision rules aggregating the achievement of wants and needs. Wants are defined as goals in terms of the parameter values defining needs when they are also defined by them. Or they are defined as goals by other parameters in vague ways. The achievement of the wants at all control points can be defined over the space of plausible cost-effective global options.

The achievement of 'global cost effectiveness' by a particular set of management options has to be defined in relation to the distance the set of options has from the set that has the lowest global cost. This involves comparison between two  $\pi(C_o)$ . The achievement of sub-global cost-effectiveness may also be important for the decision-rule.

Linguistic formulation to the aggregation can be given. An example may be, 'For option 7 it is true that all needs are met and it is very true that all wants except want 2 are met, but it is only fairly true that want 7 is met and that it is globally cost-effective.'

The algorithm enables viable CMs and ways to implement them to be defined as linguistic statements that then become part of  $SSM_1$  and  $SSM_3$  to decide what are the best CMs and best operationalisation of them; by 'experimentation' by the GES. The consequence is that the result which is technically rigorous in using all available technical analysis of the technical systems and taking all uncertainty and imprecision into account is aided in being able to be communicated as part of a conversation because the discourse is

less specific to technical discourse. It is more "user" friendly'.

Failure to obtain plausible options requires the communication of what goals (needs) are not achieved so that change can be discussed and reformulation of possible CMs obtained.

One consequence of including imprecision in the technical analyses of technical systems, for which the methods for hydrology were developed in Chapter 7, is that the non-idealisation results in the requirement of higher effectiveness and hence the imposition of greater constraints on the set of management options. The consequence of this is the need for greater recognition of risk and hence the development of trust and resilience in design. The consequence that can be expected from this is less chance of failure and also stronger development of functional viability of the social structure and so less likelihood of conflict.

On the other hand an attempt to secure a solution by arbitrarily increasing the vagueness of the definition of goals could have the opposite effect. This effectively makes them less stringent and could be the result from the failure to carry out SSM<sub>1</sub> 'experimentation'. This may not work because the goals needed to be achieved (for example protection of certain heritage or levels of resilience for business viability) may then fail to be achieved and so conflict results and so sphere 3 entered. If this happens it is because goals were made more vague out of attempts to impose structure rather than the more difficult task of embracing and nurturing individual reflexivity so as to redefine (reconstruct) CMs in a way that would maintain the integrity of the social structure. Systemic reflexivity like this is analogous to paradigm shifts which occur when the purpose for the discipline of knowledge is no longer being served even though a 'coherent' picture is able to be constructed by 'bending' things through adding unacceptable assumptions.

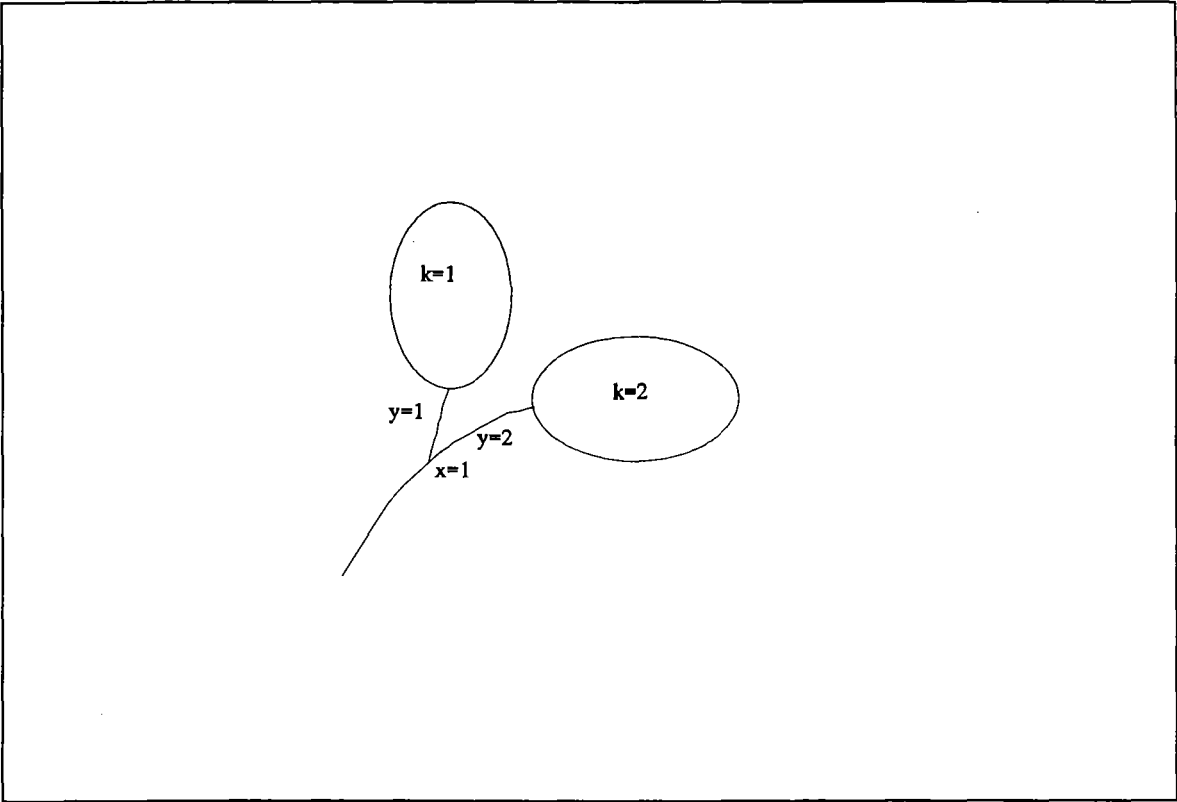
However if the algorithm is carried out appropriately then coherence and ideological coercion is avoided. Further the potential computerisation of the algorithm is an example of using computers to increase individual reflexivity in a way that extends the size in which society can be meaningfully planned and managed because communication is improved. In doing so it not only avoids the consequences that valid criticism made against hard system analysis, but also enhances the very values that are correctly used to criticise the use of computers within hard systems analysis (see Chapter 4). It can help humanize society as well as nurture sustainability.

In extending the size of society that can carry out individual reflexivity means that social organisation can be nurtured that maintains community of the 'family' type akin to

indigenous cultural organisation that is well integrated for individuals', human communities' and ecosystems' immortal life (di Zerega 1995). It may also help for example in Aotearoa/New Zealand to be a basis for enhancing common ground between the indigenous Maori and the Pakeha.

**9.3.2.1 An example.**

Below is a section of a simple example that forms part of a preliminary study for the Canterbury Regional Council on stormwater management (Morrison 1995a). The system is outlined in Figure 9.13.



**Figure 9.13;** Stormwater management example.

Plausibility constraints are: that in all sites only pond soakage and source control are available, that there are constraints on the area available for ponds, and there were also constraints on the area of soakage available; up to 50 ha for both  $k=1,2$ . Needs are concerned with achievement of water quality enabling swimming and the avoidance of flooding in the Heathcote river. Thus maximum levels of heavy metals, coliforms and water levels are used to define goals. The source levels are given by the management plan for the catchments of the Heathcote.

To simplify the example the analysis of only the three major heavy metals are

included, and goals that are wants other than cost-effectiveness are not included. The technical system analysis uses a model that incorporates the imprecision in the effect of ponding, and also in the routing of heavy metal particulate levels.

The heavy metals analyzed are lead, zinc and copper,  $i=1,2,3$  respectively.

Realistic management options (sets of management actions)  $u_{jk}$  are:

- $u_{0,1}$  soakage
- $u_{1,1}$  soakage, source control
- $u_{2,1}$  1% flood retention pond, soakage
- $u_{3,1}$  1% flood retention pond, soakage, source control
- $u_{4,1}$  3% flood retention pond, soakage
- $u_{5,1}$  3% flood retention pond, soakage, source control
- $u_{6,1}$  4% pond, soakage
- $u_{7,1}$  4% pond, soakage, source control
- $u_{0,2}$  soakage
- $u_{1,2}$  source control, soakage
- $u_{2,2}$  1% flood retention pond, soakage
- $u_{3,2}$  1% flood retention pond, soakage, source control
- $u_{4,2}$  3% pond, soakage
- $u_{5,2}$  3% pond, soakage, source control
- $u_{6,2}$  4% pond, soakage
- $u_{7,2}$  4% pond, soakage, source control

Fuzzy parameter ( $v_{ijk}$ ) and cost ( $C_{jk}$ ) values are given as trapezoidal and rectangular possibility functions respectively. Parameter values are in mg particulate/kg sediment. Cost is in \$1000.

$\pi(v_{1,0,1}) = (102)$	$\pi(C_{0,1}) = (60,80)$
$\pi(v_{2,0,1}) = (620)$	
$\pi(v_{3,0,1}) = (52)$	
$\pi(v_{1,1,1}) = (20,102)$	$\pi(C_{1,1}) = (272,392)$
$\pi(v_{2,1,1}) = (310,620)$	
$\pi(v_{3,1,1}) = (26,42)$	
$\pi(v_{1,2,1}) = (21,27,32,38)$	$\pi(C_{2,1}) = (83,147)$
$\pi(v_{2,2,1}) = (130,161,192,223)$	
$\pi(v_{3,2,1}) = (11,14,16,19)$	
$\pi(v_{1,3,1}) = (4,6,32,38)$	$\pi(C_{3,1}) = (295,459)$
$\pi(v_{2,3,1}) = (65,80,192,223)$	

$$\begin{aligned}
\pi(v_{3,3,1}) &= (6,7,13,15) & \pi(C_{4,1}) &= (120,280) \\
\pi(v_{1,4,1}) &= (9,14,20,26) & & \\
\pi(v_{2,4,1}) &= (62,93,125,155) & & \\
\pi(v_{3,4,1}) &= (5,8,10,13) & & \\
\pi(v_{1,5,1}) &= (2,3,20,26) & \pi(C_{5,1}) &= (332,592) \\
\pi(v_{2,5,1}) &= (31,47,125,155) & & \\
\pi(v_{3,5,1}) &= (3,4,10,13) & & \\
\pi(v_{1,6,1}) &= (9,9,18,22) & \pi(C_{6,1}) &= (148,330) \\
\pi(v_{2,6,1}) &= (43,74,105,136) & & \\
\pi(v_{3,6,1}) &= (4,6,9,11) & & \\
\pi(v_{1,7,1}) &= (2,2,18,22) & \pi(C_{7,1}) &= (360,642) \\
\pi(v_{2,7,1}) &= (22,37,101,136) & & \\
\pi(v_{3,7,1}) &= (2,3,7,9) & & \\
\pi(v_{1,0,2}) &= (34) & \pi(C_{0,2}) &= (60,80) \\
\pi(v_{2,0,2}) &= (237) & & \\
\pi(v_{3,0,2}) &= (12) & & \\
\pi(v_{1,1,2}) &= (7,34) & \pi(C_{1,2}) &= (92,102) \\
\pi(v_{2,1,2}) &= (119,237) & & \\
\pi(v_{3,1,2}) &= (6,10) & & \\
\pi(v_{1,2,2}) &= (5,10,11,13) & \pi(C_{2,2}) &= (150,280) \\
\pi(v_{2,2,2}) &= (50,62,73,85) & & \\
\pi(v_{3,2,2}) &= (3,3,4,4) & & \\
\pi(v_{1,3,2}) &= (1,2,11,12) & \pi(C_{3,2}) &= (182,312) \\
\pi(v_{2,3,2}) &= (25,31,73,85) & & \\
\pi(v_{3,3,2}) &= (2,2,3,3) & & \\
\pi(v_{1,4,2}) &= (3,5,7,9) & \pi(C_{4,2}) &= (330,680) \\
\pi(v_{2,4,2}) &= (12,18,47,59) & & \\
\pi(v_{3,4,2}) &= (1,2,2,3) & & \\
\pi(v_{1,5,2}) &= (3,5,7,9) & \pi(C_{5,2}) &= (362,712) \\
\pi(v_{2,5,2}) &= (6,9,47,59) & & \\
\pi(v_{3,5,2}) &= (1,1,2,2) & & \\
\pi(v_{1,6,2}) &= (2,4,6,7) & \pi(C_{6,2}) &= (420,860) \\
\pi(v_{2,6,2}) &= (17,28,40,52) & & \\
\pi(v_{3,6,2}) &= (1,1,2,3) & & \\
\pi(v_{1,7,2}) &= (5,1,6,7) & \pi(C_{7,2}) &= (475,915)
\end{aligned}$$

$$\pi(v_{2,7,2}) = (9,14,40,52)$$

$$\pi(v_{3,7,2}) = (.5,.5,1.5,2)$$

Cost-effective management options ( $C_{jk}$ ) for  $k=1$ :

$$\pi(C_{0,1}) = (60,80)$$

$$\pi(C_{2,1}) = (83,147)$$

$$\pi(C_{4,1}) = (120,280)$$

$$\pi(C_{6,1}) = (148,330)$$

$$\pi(C_{7,1}) = (360,642)$$

Cost-effective management options ( $C_{jk}$ ) for  $k=2$ :

$$\pi(C_{0,2}) = (60,80)$$

$$\pi(C_{1,2}) = (72,102)$$

$$\pi(C_{2,2}) = (150,280)$$

$$\pi(C_{3,2}) = (182,312)$$

$$\pi(C_{4,2}) = (330,680)$$

$$\pi(C_{5,2}) = (362,712)$$

$$\pi(C_{6,2}) = (420,860)$$

$$\pi(C_{7,2}) = (475,915)$$

Cost-effectiveness is used to check that the cost values form an increasing function.

It is necessary that it remains absolutely true that differences between options can be calculated.

Inverse of marginal cost of subsystem options for  $k=1$  has steps fulfilling the need for a strict necessary difference in cost, from  $u_{0,1}$  to  $u_{2,1}$  to  $u_{6,1}$  to  $u_{7,1}$  for  $i=1$

for  $u_{0,1} \rightarrow u_{2,1}$

$$\pi(\Delta v) = (-81,-75,-70,-64)$$

$$\pi(\Delta C) = (3,87)$$

$$\therefore \pi(\Delta v/\Delta C) = (-27,-25,-.8,-.7)$$

for  $u_{2,1} \rightarrow u_{6,1}$

$$\pi(\Delta v) = (-29,-23,-9,0)$$

$$\pi(\Delta C) = (1,247)$$

$$\therefore \pi(\Delta v/\Delta C) = (-29,-23,-.04,0)$$

for  $u_{6,1} \rightarrow u_{7,1}$

$\pi(\Delta v)$  cannot be defined (not a strict necessary difference)

for  $i=2$

for  $u_{0,1} \rightarrow u_{2,1}$

$$\pi(\Delta v) = (-490, -459, -428, -397)$$

$$\pi(\Delta C) = (3, 87)$$

$$\therefore \pi(\Delta v / \Delta C) = (-163, -153, -5, -4.5)$$

for  $u_{2,1} \rightarrow u_{6,1}$

$\pi(\Delta v)$  cannot be defined.

for  $u_{6,1} \rightarrow u_{7,1}$

$\pi(\Delta v)$  cannot be defined.

for  $i=3$

for  $u_{0,1} \rightarrow u_{2,1}$

$$\pi(\Delta v) = (-41, -38, -38, -33)$$

$$\pi(\Delta C) = (3, 87)$$

$$\therefore \pi(\Delta v / \Delta C) = (-14, -13, -.4, -.4)$$

for  $u_{2,1} \rightarrow u_{6,1}$

$$\pi(\Delta v) = (-15, -10, -5, 0)$$

$$\pi(\Delta C) = (1, 247)$$

$$\therefore \pi(\Delta v / \Delta C) = (-15, -10, -.02, 0)$$

for  $u_{6,1} \rightarrow u_{7,1}$

$\pi(\Delta v)$  cannot be defined.

for  $k=2$  steps occur from  $u_{0,2}$  to  $u_{2,2}$  to  $u_{4,2}$

for  $i=1$

for  $u_{0,2} \rightarrow u_{2,2}$

$$\pi(\Delta v) = (-29, -24, -23, -21)$$

$$\pi(\Delta C) = (70, 220)$$

$$\therefore \pi(\Delta v / \Delta C) = (-.4, -.35, -.1, -.1)$$

for  $u_{2,2} \rightarrow u_{4,2}$

$\pi(\Delta v)$  cannot be defined

for  $i=2$

for  $u_{0,2} \rightarrow u_{2,2}$

$$\pi(\Delta v) = (-187, -175, -164, -152)$$

$$\pi(\Delta C) = (70, 220)$$

$$\therefore \pi(\Delta v / \Delta C) = (-2.7, -2.5, -.7, -.7)$$

for  $u_{2,2} \rightarrow u_{4,2}$

$\pi(\Delta v)$  cannot be defined.

for  $i=3$

for  $u_{0,2} \rightarrow u_{2,2}$

$$\pi(\Delta v) = (-9,-9,-8,-8)$$

$$\pi(\Delta C) = (70,220)$$

$$\therefore \pi(\Delta v/\Delta C) = (-.13,-.13,-.04,-.04)$$

for  $u_{2,2} \rightarrow u_{4,2}$

$$\pi(\Delta v) = (-3,-2,-1,0)$$

$$\pi(\Delta C) = (70,220)$$

$$\therefore \pi(\Delta v/\Delta C) = (-.04,-.03,-.005,0)$$

Cost-effective management options that lie in between the steps are assumed to have inverse marginal cost levels the same as the overall step they lie within. A notation can be used to indicate this, e.g for  $k=1$  and  $i=1$  the end point of the step  $u_{0,1} \rightarrow u_{2,1}$  can be written as:  $\langle [1,1];[2,1] \rangle$ .

Consider intersection  $x=1$ . To determine a cost-effective sequence of sets of management options the inverse marginal costs are compared for incremental improvements in parameter effectiveness. To carry out this comparison using the water quality model that routes parameter values requires multiplying values of particulate levels by the sediment level. The adjusted values allowing comparison are given by Table 9.2.

k	i	$u_{jk} \rightarrow u_{jk}$	$\pi(\Delta v/\Delta C)$
1	1	0→2	(-3375,-2875,-100,-88)
	1	2→6	(-3625,-2875,-5, 0)
	2	0→2	(-20375,-19125,-625,-563)
	3	0→2	(-1750,-1625,-50,-50)
	3	2→6	(-1875,-1250,-2.5, 0)
2	1	0→2	(-38,-33,-10,-10)
	2	0→2	(-257,-238,-67,-67)
	3	0→2	(-13,-13,-4,-4)
	3	2→4	(-4,-3,-.5, 0)

**Table 9.2;** Fuzzy cost-effectiveness.

Therefore the sequence for  $i=1$  is  $u_{2,1}$  then  $u_{6,1}$  or  $u_{2,2}$  then all other steps that are not able to be differentiated.



For  $i=2$ :  $u_{2,1}$  then  $u_{2,2}$  then all others.

For  $i=3$ :  $u_{2,1}$  then  $u_{6,1}$  or ( $u_{2,2}$  then  $u_{4,2}$ )

Therefore overall the sequence is:

$u_{2,1}$  then  $u_{2,2}$  then  $u_{6,1}$  or  $u_{4,2}$  then all other steps.

There are therefore eight possible combinations of sequences of global management option sets that cannot be differentiated in relation to their achievement of the goal of cost-effectiveness. One of them is written out in full below:

$\{(<0,1>,<0,2>),(<2,1>,<0,2>),(<2,1>,<[1,2],[2,2]>),(<[4,1],[6,1]>,<2,2>),(<6,1>,<[3,2],[4,2]>),(<7,1>,<4,2>),(<7,1>,<5,2>),(<7,1>,<6,2>),(<7,1>,<7,2>)\}$

Global management option sets that achieve other wants should also included in here as possibilities thus enabling comparison of the degree to which they are achieved with cost-effectiveness.

The routing model is then used to calculate the parameter values at the intersection. Composite costs are also calculated. See Table 9.3 as an example for the composite values for  $i=1$  for the endpoint values of each step making up the sequences.

$(u_{j1}, u_{j2})$	$\pi(C_{jk})$	$\pi(v_{ijk})$
$(<0,1>,<0,2>)$	(120,160)	(73)
$(<2,1>,<0,2>)$	(143,227)	(27,30,33,36)
$(<2,1>,<[1,2],[2,2]>)$	(223,427)	(15,20,23,27)
$(<[4,1],[6,1]>,<2,2>)$	(413,827)	(14,18,22,25)
$(<6,1>,<[3,2],[4,2]>)$	(478,1010)	(6,7,14,16)
$(<7,1>,<4,2>)$	(510,1042)	(6,7,13,16)
$(<7,1>,<5,2>)$	(568,1190)	(6,6,13,16)
$(<7,1>,<6,2>)$	(623,1245)	(5,5.5,13,15.5)
$(<7,1>,<7,2>)$	(835,1557)	(1,2,13,15.5)

**Table 9.3;** Fuzzy costs of management options.

Note that in consideration of the inverse marginal cost at this intersection, when considering the network downstream, all values are cost-effective but the only steps used

to calculate marginal cost is from composite set 1 to set 3.

Considering intersection  $x=1$  to be a control point, values of parameter effectiveness there enables the achievement of the needs to be determined. The goals for the parameters are defined by ramp functions given by:

$$\pi(g_1) = (31,200,+\infty)$$

$$\pi(g_2) = (120,400,+\infty)$$

$$\pi(g_3) = (10,40,+\infty)$$

The result is eight constrained sequences of composite management option sets which are open for consideration if the system is considered as part of a larger network. The 'cheapest' global management option that is to some extent true for all parameters is  $(\langle 6,1 \rangle, \langle 4,2 \rangle)$ . Therefore this is taken as the basis for what is cost-effective. Note that it makes no sense to have cost-effective options which do not fulfil what it is to be cost-effective about. Therefore options that do not fulfil needs are also not cost-effective or more accurately are not evaluated for cost-effectiveness - no statement about cost-effectiveness can be made.

The different degrees of achievement of the goals of both needs and wants can then be given for the sets of global management options making up the sequences. The global management options are able to be linguistically described thus:

$$(\langle 0,1 \rangle, \langle 0,2 \rangle)$$

'It is absolutely false that need 1 is met and false that needs 2 and 3 are met.'

$$(\langle 2,1 \rangle, \langle 0,2 \rangle)$$

'It is false that the needs 1,2, and 3 are met.'

$$(\langle 2,1 \rangle, \langle 2,2 \rangle)$$

'It is absolutely true that need 1 is met but false that needs 2 and 3 are met.'

$$(\langle 2,1 \rangle, \langle 4,2 \rangle)$$

'It is absolutely true that need 1 is met and true that need 3 is met but false that need 2 is met.'

$$(\langle 6,1 \rangle, \langle 4,2 \rangle), (\langle 6,1 \rangle, \langle 5,2 \rangle), (\langle 6,1 \rangle, \langle 6,2 \rangle), (\langle 6,1 \rangle, \langle 7,2 \rangle)$$

$$(\langle 7,1 \rangle, \langle 7,2 \rangle)$$

'It is absolutely true that needs 1,2, and 3 are met and true that they are cost-effective.'

Management options that attempt ever greater effectiveness than those considered realistic management options will eventually produce options for which it is false that they are cost-effective. Consideration of wants other than cost-effectiveness could produce some discrimination between the last plausible five options. That the five options exist

for which consideration of other wants are the deciding factor shows the value of such an approach. It leaves scope for realistic choice without artificially constraining it by pseudo-optimisation which would limit the consideration of all pertinent goals and values held by society.

## **9.4 CONCLUSION**

To face the issues of social structure required rejecting the assumptions underpinning behavioural decision-theory. However in facing the underlying theory a way to develop the structure of the theory without rejecting it for where it is applicable was achieved. But a philosophical shift from positivism to phenomenology has been required.

Insight from hierarchical models and communication theory has enabled a dynamic model to be developed that is consonant with SSM. Synthesizing a decision-model able to be applied within SSM with a coherent information structure has enabled an algorithm to be developed that is 'intelligent'. It is both efficient as well as being receptive to information gained from within the SSM process.

Further development is required to fully computerise the process and to interface it with the publics. The hardware exists for this to be achieved. Further work is however required to create the software.

# **Floodplain Management**

There is not much literature explicitly focused on this topic. Even if it is extended to natural hazard management it is not extensive. As a topic it is not one which has attracted research so as to build up a tradition of discussion and debate. However a development in the research does exist and some critical reflections are included in it at the level of methodology.

As mentioned in the introduction, the lack of rigorous methodological work in the face of never-the-less serious issues prompted the research here to explore the component disciplines making up the knowledge base for floodplain management. From a critical review of these in the way they apply to floodplain management, a critical reflection on floodplain management methodology as it stands at present has been made. However as this serves little purpose where there is not a forum for active debate about the issue the focus has been on reconstructing a methodology as a possible alternative that stands up to the criticism and which is based on the reconstruction found appropriate in the component disciplines.

## **10.1 INTRODUCTION**

Floodplain management is in practice a multi-disciplinary activity. Also it has been found, through analysis of the component disciplines involved in it, that in theory it should be. This underlines the existence of complex interactions that have also to be appreciated.

A review of the dynamics involved, including a historical review of the social construction of floodplain management and floods, is carried out in this chapter. From this an outline of what the different roles and expertise required for floodplain management is given. Finally an outline of what is an appropriate floodplain management methodology is developed in light of this and the analyses from previous chapters.

The outline of an appropriate methodology is a reconstruction to fulfil the meta-ideals of sustainability, bio-diversity and social justice focused on. It is an application of the general reflexive methodology developed in previous chapters. A hopeful approach is made which is based on interpretations which see economic processes as potentially reciprocity, and social relationships generally as potentially based on trust, understanding and cooperation.

10.2 THE CONTEXT AND DYNAMICS OF FLOODPLAIN MANAGEMENT

Several analyses have been developed in preceding chapters which give perspectives on the context and dynamics involved in management systems. The central one used to integrate all others is that of the reflexive spheres. To gain an appreciation of the context, the interaction of the spheres is considered so as to scope the issues of floodplain management that need to be addressed.

Because of the nature of the third sphere a genealogical analysis of its impact on the two outer spheres is appropriate (see Chapter 4). The transcendental system of sphere 3, by definition, is not definable and is the 'inner space' with all the paradoxes that Pirsig (1974) ascribes to 'quality'. So observation of it is only possible from the effect it has on the expression of the other spheres. It is the source and ground of all the other spheres and so everything reveals it in some way. However the specific expression by humans revealing the effect of reflexive awareness of it is the most pertinent. Specifically, the functional integration and reciprocity in the ground of caring explored in postmodern ethics reveals it vividly.

The result is a dynamic and ecological/spiritual dialectic that synthesizes time/space and the timeless/inner space. The bridge is the expression of language giving principles

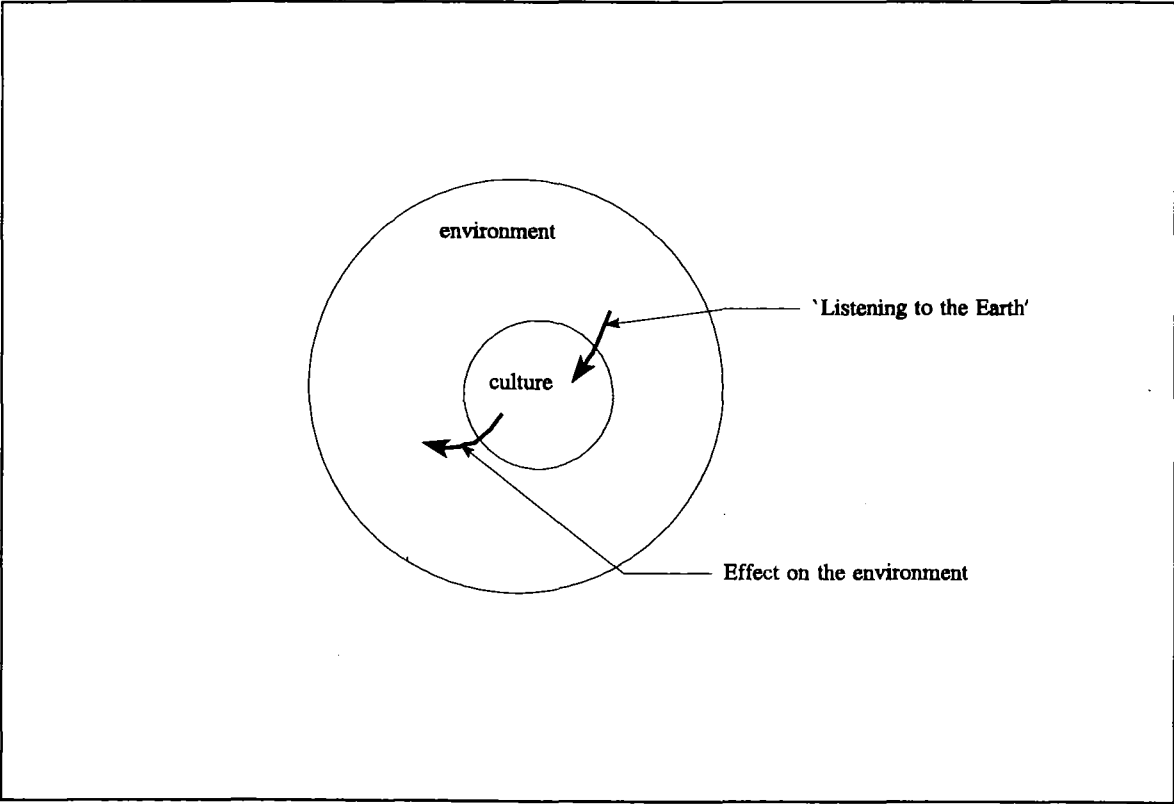


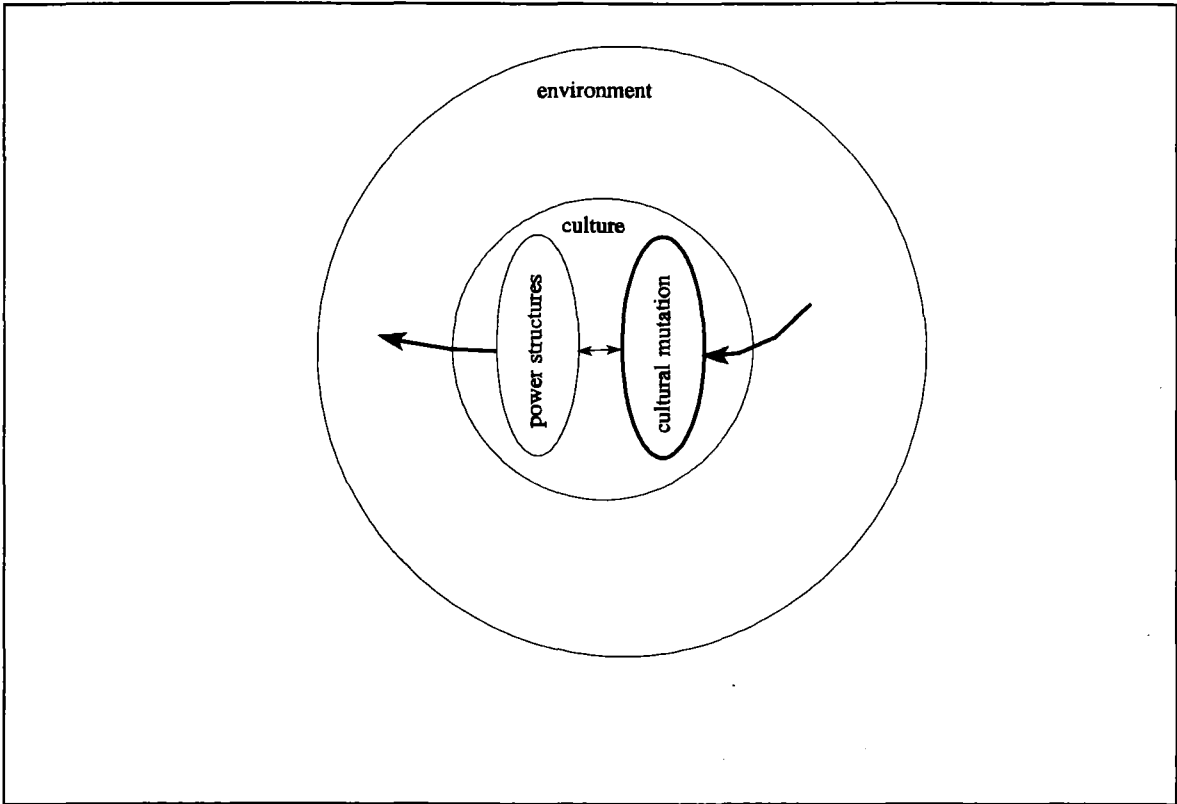
Figure 10.1: Culture/environment interaction.

and norms for behaviour. Figure 10.1 gives the most simple outline of what the dynamic is. The feedback from the environment onto culture is second-order feedback (see Chapter 4). However it fails to indicate the role of structural power and the co-evolutionary process whereby the culture's power structures evolve in response to the interaction.

Figure 10.2 outlines a simple way to show the co-evolutionary process.

A pertinent example of a culture that has gone through this process is the Maori culture of Aotearoa/New Zealand. Over a period of approximately 700 years adaptation through change of the culture to become one that was sustainable in a temperate rather than tropical ecosystem occurred. The evolution is seen in changes to mythology as well as in practices (Patterson 1992).

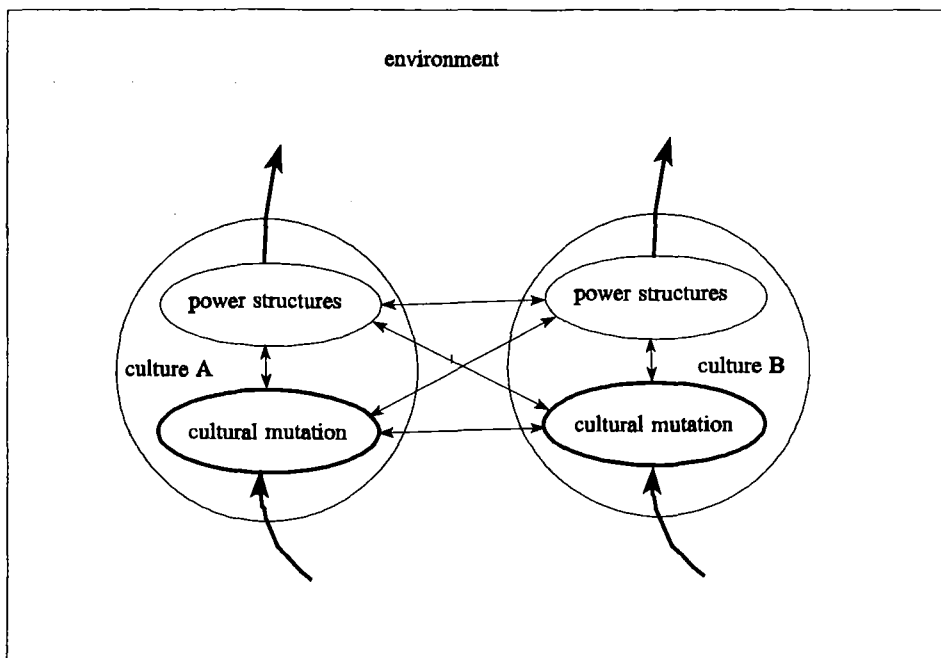
A common situation since European colonization and the introducing of new culture, where human cultures already exist, is given in Figure 10.3. This is the situation in



**Figure 10.2;** Culture/environment co-evolution.

contemporary Aotearoa/New Zealand. The two dominant cultures are co-evolving together and within the environment.

The significant features of the dynamics for floodplain management are the feedbacks from the environment into culture, as well as the interaction between the elements in a



**Figure 10.3;** Inter-cultural/environment co-evolution.

culture. As already explored, the feedback from the environment has two elements. It involves scientific monitoring based on objective analysis and relying on non-reflexive rational reflection on sphere 1; and also wisdom gained from openness to sphere 3, often called 'listening to the Earth' (Snyder 1990 and O'Connor 1993 and Morrison 1995b). The interaction between elements in a culture is here specifically considering the interaction between those receiving feedback from the environment, and those who are not and maintaining the existing human effect on the environment. In other words, the dynamic of the social construction of flood hazards.

It can be expected that breakdown in the feedback system occurs because scientific monitoring is not incorporated into decision-making and/or wisdom is not appreciated.

As discussed already, scientific information is not incorporated when information is considered an externality as it is in a market (see Chapter 8). Also the non-appreciation of wisdom is a consequence of a culture not being reflexive because of the holding of rationalist epistemologies and/or naturalistic legitimization of truth. Both result in cultures that have a dogmatic ideology and abuse power. Dominant Western culture using naturalistic legitimization, and adhering to a fatalism because of it, makes it particularly averse to appreciating wisdom and even learning from other cultures. Therefore second-

order feedback is not being received and so the social construction of flood hazards is not able to be appropriately evolved. Adaptation allowing sustainability is not being achieved.

Never-the-less in general, inertia is expected and is necessary for social stability. Society exists because of collective worldviews representing relatively stable language games which occur to be social structure. However when the learned activities adhering to power relations can end up being justified ideologically and expressing symbolic violence to legitimize social injustice and ecological degradation, the worldviews require critique and attempts at reconstruction based on 'listening' to second-order feedback. It is the contention of the research here that this is generally true for contemporary Western culture and also specifically true for the engineering profession and resource management including floodplain management. However there is the added subtlety that there has also been the loss of traditions that give stability and represent activities that are still adapted to the environment. In contemporary Western cultures there is mis-directed adaptation (counter-adaptive adaptation) through the Enlightenment (see Chapters 3 and 4).

Some progress is being made in correcting the situation however. It is expressed in the symbolic exchange between groups to help in the cooperative endeavour to cope with the uncertainties socially and environmentally. This is occurring in New Zealand in three main areas:

(i) Reconciliation between the indigenous people (the Maori) and the recent European (Pakeha) colonisers based on the symbolic importance of the Treaty of Waitangi as a founding document for justice between indigenous people and recent colonisers.

(ii) Reconciliation between people and the ecosystems being inhabited. This involves seeking reconciliation between the various social groups who have various advocacy roles; those for the environment, those for recreation and those for business activity. But it goes further, as recognition of the intrinsic values existing outside of human beings is also made. Pakeha becoming aware of Maori culture is encouraging this. The Deep ecology movement is encouraging it also.

(iii) Affirming heritage symbols which give guidance to the reconciliatory process and the ideal of symbiotic harmony. These are both natural heritage and cultural heritage. There is a fair degree of overlap between (iii), (i) and (ii). However (iii) can involve symbols or 'tokens' of what has to be attempted fully through (i) and (ii). For example scenic reserves do not produce integration within ecosystems with adequate recognition of bio-diversity nor respect of intrinsic values, but they help point toward and encourage people to do so. Similarly, small wetlands for Maori collecting of traditional weaving



materials do not implement the Treaty of Waitangi, but they point toward what is required, and help develop understanding.

What is needed, and what this research has attempted to lay the groundwork for, is a comprehensive integrative resource management methodology applicable for floodplain management along with other issues that institutionalizes both the need for stability of social structure through recognition of the value of pertinent tradition yet also openness to the third sphere so as to allow multi-cultural adaptation to occur.

### **10.3 THE FLOODPLAIN SYSTEM**

A definition of the system is required. A system boundary according to the various spheres is required. The analysis must start with sphere 2 as this is the context of social construction from within which decisions are made. The floodplain system in sphere 2 is the management system. Historically this has had different boundaries and is discussed in a later section. However both regional contexts of the physical floodplain and catchment, and wider political boundaries, are part of it. Occasionally there are attempts to give international or even global contexts as well. These institutional boundaries form a 'bottom line' that are the significant aspects of the language game creating the dominant interactions.

There are also two theoretical criteria which can be deduced from the systems analysis of Chapter 4 to define what the management system boundary should be. An ecological one and a community one. These need to creatively inform the language game in the way discussed in Chapters 4 and 9. The ecological one is concerned with biodiversity and sustainability and, if they are able to be achieved or enhanced, means that the bio-region that a floodplain and catchment are in needs to be appreciated, and allowed to present the form to base the framing of human activities on, i.e 'management' of the system. The other principle is that of the need to nurture community relationships so that reflexive learning or ontological growth occurs.

The reflexive spheres need to be incorporated into the discussion to appreciate this. The boundaries between the three spheres need to be drawn so as to ensure that sphere 1 is not defined so broadly that community relationships are not possible. In defining this boundary it limits the functional relationships making up social services in sphere 2. It means that only those services under the control of floodplain communities, i.e. those paid by rates and endogenous to the region/district, are those that belong to sphere 2. So all wider political processes and services, e.g. law, national subsidies and relief, insurance, and market (trade) interactions are part of the environment. This can extend to

international/global 'services' as well, e.g. GATT and Agenda 21. This means that the system needs to be defined to be resilient in face of changes that occur in these environmental effects, including the effect of law and one of its creations, the market institution.

Definition of the system in terms of the other spheres is able to be derived from the system defined for sphere 2. Humans are involved in 'listening' to sphere 3 so as to respond appropriately and so sphere 3 in total is part of the system then so everywhere 'the whole is in each part', so systemic reflexivity is individuated and ontological growth occurs. This fulfils the meta-ideal of ethics and leads to appropriate consideration of sustainability, bio-diversity and social justice (see Chapter 3).

In the outer sphere 1, the boundary is defined by what management considers has to be integrated. Ecosystems and physical features (e.g. rivers) of the floodplain and catchment are part of the system. Weather and diseases that transcend the boundaries of specific ecosystems, are part of the environment. This may even extend to the global context if global warming has an effect on water levels.

### **10.3.1 The ideal.**

The ideal has been implicitly defined above in the analysis of the reflexive system which inspires ontological growth. However it has to be seen as being operationalized in sphere 2. What is required is a management institution that allows for feedback from the environment to be critically evaluated and integrated into the management process. Further that the management system needs to be simple in the sense of having a coherent perspective that appreciates and promotes trust and the spirituality of 'listening to the Earth' so that it is wise and 'healthy'.

Finally the reciprocity and integration seen in ecosystems should be sought for human communities as well, within themselves and in their involvement within the ecosystems they belong to. What this requires is also trust nurtured through caring from awareness of the sacred leading to the ethical relation (see Chapter 3). It is encouraged by protocols and ceremony that respect openness and creativity to improve the situation, i.e. to give hope.

### **10.3.2 How it is and has been.**

That there are issues of conflict reaching sphere 3 indicates that there is much wrong with existing floodplain management. The relationships between the power structure and those expressing feedback from the environment is one of conflict. The conflict indicates

that social justice and ecological integration are not being achieved.

In attempts to redress the imbalance, many pressure groups are lobbying. They are mainly environmental groups attempting to preserve indigenous ecosystems, but there are also groups concerned for other humans disadvantaged by existing structural power, as well as commercial interest groups.

The problem is in the lack of successful interaction between those expressing the feedback from the environment and those maintaining power structures. The reason is because of ideology that makes it very difficult for the power structures to face up to the problem. Community relationships of trust and dialogue to create wise development pro-actively are not recognised formally as part of the system. This issue is further developed in later sections.

Unfortunately the engineering profession has no clear agenda to promote wise development so as to be proactive on this account. This is also developed in later sections.

Some exceptions are some of the Maori communities. This is not surprising when considering the adaptation model outlined above. It has been found that Pakeha communities are less likely to be able to pro-actively discuss what their concerns are for community development on floodplains because they do not have a forum within which to do so. In contrast Maori have protocols in regular use to do so about such issues that come up in the life of the community (Hall 1991).

Traditionally Maori adaptation to their new environment so as to be integrated into the ecosystems involved little modification of floodplains. An exception is the opening of Waihora (Lake Ellesmere) to lower the lake level as it filled and flooded settlements. Fishing in wetlands was very important for Maori and so draining was not carried out. Crops were not extensively relied upon, especially in Te Wai Pounamu (the South island of New Zealand) and so there was no pressure to create farmland. Also the worldview has respect for intrinsic values and promoted sustainability and integration into ecosystems. Settlements, while sometimes affected by flooding, were usually on terraces or were temporary.

When European (Pakeha) colonization occurred approximately 1000 years after the Maori colonization, the culture that was brought had a far greater impact on the environment generally, and in particular on floodplains. There were three main reasons for this.

1. As for Maori, transportation was initially by sea and river. Towns grew close to the rivers, especially on low tidal floodplains. Differently from Maori, the riverside towns

were meant to be permanent.

2. Differently from Maori, cropping was crucial and fertile wetlands not requiring irrigation were prime land in which to grow them. ...So they have been extensively drained. This repeats the extensive wetland draining carried out in the Middle Ages in Europe. As with the period in the Middle Ages, it involved cutting down of the lowland forest as well.

3. Differently from Maori, the dominant worldview was/is not respectful of intrinsic values, and a sense of balance has yet to be gained. Even though natural events have been seen as 'acts of God' that was particularly reserved for bad ones like flooding. Instead of a spirituality promoting respect for Nature, and trust and integration into ecosystems, a fatalistic attitude was held, with God being seen as using Nature to punish rather than contemplated within as sacredness and wholeness.

However the extreme despoiling of ecosystems that has occurred from European colonization has resulted in pressure groups (Maori and Pakeha) attempting to change the power structures and dominant ideology in the attempt to 'listen' to the feedback from the environment. Hopefully this research will also help.

Flooding was a major hazard and drowning was a major cause of death in early European settlement. With this and the rapid development of agriculture, when trade to England was enhanced by refrigerated shipping, there was pressure to protect the, by then, established floodplain settlements and agriculture. Flood protection work was however carried out in the despairing battle against a vengeful God (sic).

As economic development grew with increased trade, the process of legitimizing and financing of flood protection became formalized. The use of CBA began in the United States to legitimize public spending on flood protection and it was soon carried out in New Zealand as well.

A national context was used with a single criterion to increase agricultural production (McIntyre 1985). Subsidies were given to construct flood protection, and relief given when disasters resulted. Urban costs were not included in the CBA carried out to decide on whether or not a protection work was feasible. The resulting urban flooding that occurred and increased was lumped with relief that was given in response to 'acts of God'. A National Water and Soil Conservation Authority (NWSCA) was instituted to carry out the floodplain protection works. It is often suggested that it was not floodplain management that was being carried out but rather flood protection (Ericksen 1986). But in a deeper analysis it was floodplain management; floodplain management with a particular agenda not recognized by those implementing it because the ideology involved

was so unquestioned.

The single criterion development continued until the early 1970s when the market with England for Aotearoa/New Zealand agricultural produce collapsed when England joined the EEC. No longer did Aotearoa/New Zealand have a guaranteed market which allowed economic development to be achieved by simply increasing agricultural development. The environment changed.

As the economy plummeted the economic ability to pay subsidies and relief became questioned. Also the Maori environmental voice became stronger. In the late 1980s a shift toward a regional context was made with the institution of Regional Councils and with this shift national funding decreased markedly. Pakeha culture's power structures were beginning to respond to feedback from the environment. The original European floodplain management system proved itself to be inadequate as it was not resilient in the face of change in the environment. At the same time reflexive consideration of the floodplain management system began in New Zealand (Ericksen 1986).

### **10.3.3 Methodologies**

There are three main methodologies; the market approach, the ecological model and integrated management.

#### **10.3.3.1 The market approach.**

The approach most consonant with the underlying ideology of western culture, and so the default expression, is the market. To reflexively expound it is in effect to point out existing 'bottom lines' of existing social institutions and hence ways to maintain social integration.

It is the approach that was followed rigorously in New Zealand until the economic collapse in the 1970s. It has been developed formally and is still used worldwide, especially in development projects seeking economic growth along the lines of Western economies (Fitzgerald 1978), and see Boyce (1990) for a critical review of the practice.

It is not community nor ecosystem based. It is explicitly based on the concept of symmetry without concern for hierarchical integration (see Chapters 4 and 8). Also risk and ethical principles are not incorporated in an explicit way. Rather production is seen to be the basis for social improvement and even safety (Wildavsky 1980).

A tradition of manuals was developed to implement the approach for floodplain management (e.g. Parker et al. 1987).

### **10.3.3.2 Ecological model.**

This was the outcome of critical reflection on the failure of the market approach. In the 1950s and 1960s in the United States, questioning of the market approach began because of the flood damage paradox which came to be observed. The market was observed to be failing and even exacerbating the situation. Therefore an equilibrium approach was questioned, and instead the process of floodplain development came to be considered. The process came to be seen instead as one of a process of flood mitigation in response to flooding. So detailed lists of specific ways to minimize flood damage and avoid flood damage were developed for practical help (e.g White 1961).

The model developed into a general adaptation model described as the human ecology of floodplains. Various contexts, from the local to the national and the international were considered in terms of how to adapt to natural hazards (White 1974 and Burton et al. 1978).

The methodology was based upon general systems theory (GST). With the change in economic environment for Aotearoa/New Zealand and with the market mode becoming inoperative, NWSCA made a shift toward the ecological model (e.g Ericksen 1981). Urban flood damage became of importance. As McIntyre (1985) put it, (Aotearoa)/New Zealand followed United States 25 years behind.

However the ecological model has been criticized. Torry (1979) argues that the structural injustice is not addressed. The cultural dimension is not considered, and so in effect it is Eurocentric and also capitalist oriented in its analyses. It does not critically consider the worldview of modernity and the associated privileging and essentializing of science and technology. This occurs not only in unreflected acceptance of existing social power relations in the Western societies, but it is also seen as a model to apply to 'developing' nations so as to promote the Western social system (e.g. Boyce 1990). the need for appropriate hierarchical integration is not appreciated.

### **10.3.3.3 Integrated management.**

From literature in the social sciences applied to environmental management, the critique of the ecological model has been taken seriously. It has been carried out by political economy studies in geography (e.g Blaikie 1985) in the tradition of critical social science. It has also been taken to mean the need for democratization of management of natural resources (Daneke et al. 1983 and Culhane et al. 1987). The role of public participation came to be seen as central. Thus the issue of the need for reflexivity almost came to be explicit.

In Aotearoa/New Zealand this occurred with the change from a national to a regional context for floodplain management which meant that a national standard methodology was no longer applied. While this was lamented by some (e.g. Peacock 1991), others saw it as allowing more appropriate regionally specific methods to be applied (e.g. Munn 1991). However it can be argued that both views miss the crux of the issue, that a coherent methodology should be able to be general so that it can be applied to specific contexts, and one had not yet been developed. In light of the lack of general acceptance of the ecological model as an adequate general theory, some Regional Councils dropped the method formerly promoted by NWSCA and looked toward applying integrated management instead for floodplain management, e.g. Canterbury Regional Council and Hawke's Bay Regional Council. Research concerned with integrated management, and to some extent patronized by the Regional Councils, has been carried out in an attempt to develop a coherent general methodology ( e.g. Blackford 1990a, 1990b; Blackford and Matunga 1994 and Pyle and Gough 1991). It has yet to be successfully integrated into floodplain management however. It is argued here that the main stumbling block has been that an analysis of systemic dynamics thus allowing a thorough deconstruction and reconstruction has not been achieved. This research attempts to redress that problem so as to define appropriate hierarchical levels for integration and how to operationalize it.

#### **10.4 MULTI-DISCIPLINARY EXPERTISE REQUIRED FOR FLOODPLAIN MANAGEMENT**

The different disciplines required are:

- \* sociologists
- \* mediators, including Maori consultants.
- \* ecologists
- \* hydrologists
- \* information technologists
- \* risk analysts.
- \* lawyers
- \* economists
- \* design engineers.
- \* resource manager/engineer.

In Aotearoa/New Zealand experts from the various disciplines are contracted in as consultants and/or are on Council staff. The Councils attempting to carry out integrated management make more use of specialized consultants, e.g. the Wellington Regional

Council and the Canterbury Regional Council. The Otago Regional Council by contrast claimed to not use any consultants whatsoever in the context of floodplain management.

In the face of the need for deconstruction so as to be open to 'hear' feedback from the environment and to reconstruct accordingly, the roles of authority in the power structures need to be reflexive so as to be self-critical of the underlying assumptions they make in methodologies, and to be open to other worlds expressed among others which legitimize and reproduce interactions with the environment.

To do this a philosophical understanding of the disciplines the experts belong to is required so as to integrate methodologies, e.g. as carried out in Chapters 3 and 9. Understanding of the sociology of their discipline is helpful, e.g. the sociology of science. An appropriate double hermeneutic is required (see Chapter 4). Sociologists who can do so and can integrate the perspectives are required for the multi-disciplinary team. If disciplined sociological help is not available, or is unsuitable to carry out the required deconstruction, then others involved must seek to gain a firm sociological understanding of their discipline - like for example that developed in this research for the engineering profession. As well as the role of sociologists to promote critical reflection by all the disciplines of expertise so as to be reflexive, and thus allow the multi-disciplinary process to work, there is the need for sociologists to analyze the social system of the floodplain as well.

As discussed in Chapter 8 the economics discipline is problematic because it has definite schools of thought along strong ideological lines. It has been concluded in Chapter 8 that the dominant neo-classical tradition is inappropriate for resource management including floodplain management, and that economists to be of help in the process should be working according to Postmodern principles of reconstruction. If appropriate economic expertise is not available, then sociologists or practitioners from social geography disciplines may be able to carry out the task adequately. Failing that, manager/engineers with a critical understanding of economic methodology as it pertains to resource management, as developed in this research, may be adequate.

Ecological expertise is required to determine the requirement for functional integration into ecosystems, and hence to provide the technical information required to enhance biodiversity. Environmental ethicists to point out the ethical dimension would also be helpful.

Hydrologists who are able to carry out realist analyses by handling the mathematics of uncertainty are required. This is problematic as the discipline is yet to fully face this issue. Hopefully the development carried out by this research will help in this matter.



Information technologists are required to construct the ESs and interface them with GIS. As yet software is not available for the task. This is a step of development to be taken starting from the research carried out here, especially in Chapter 9.

Risk analysts must be able to approach the situation from the point of view of social risk so that the reflexivity required to perceive the social construction of risk and hazard is part of their discipline.

#### **10.4.1 The role of the engineer.**

Engineers, in their role as resource managers for floodplain management, are obliged to have an understanding of the disciplines involved and how to integrate them, as carried out in this research. Also, however, engineers have specific expertise in hydrology, information technology, risk analysis and in design.

But whatever their specific expertise, as professionals, engineers need to know their context and hence their place in decision-making (see Chapter 3). Generally in the multi-disciplinary context, it is as an aid for social goal definition (information technology) and technical analysis. This has to be carried out critically, rigorously and reflexively so as to not engage in structural power relations via methodology that is incorrect and legitimizes injustice by being unrealistic to the context. This is where some understanding of the sociology of engineering and ethics is required. With an appreciation of the context, engineers are able to endeavour to carry out their analyses in a constructive way so as to improve society and the ecosystems they and those they serve live within. However to do so is in conflict with the classical role of an engineer (see Chapter 3).

A reconstructed methodology requires to aim to correct the structural power relations of professional competition and collusion. What has to change is engineers submitting to market expectations in an irresponsible abuse of their credibility and the pedigree of their truth. For example a Christchurch engineering consultancy have had an overseas consortium client wanting to develop a golf tourist resort on the Waimakariri floodplain. The application was made before a regional plan was finalized even though the draft plan made it clear that the planned development would be unacceptable. So the proposal was taken to court. The consortium proved to be poor clients for the engineering consultancy because they were slow to pay their bills and they had reportedly been seriously considering whether or not to 'change sides' to support the council. The question has to be asked: where is the truth in any legitimate sense of the word in analysis that can change depending on who is buying it? For hydrological engineers to ply their profession competitively in a market, with truth being merely a sales ploy and instrument

of power in an adversarial debate, means that they have an unacceptable self-image.

## **10.5 APPROPRIATE FLOODPLAIN MANAGEMENT METHODOLOGY**

The context in which floodplain management is carried out has been given in systems concepts in Section 10.2 and based on the systems theory developed in Chapter 4. Also the genealogical unfolding/co-evolving of the systems has been briefly sketched, along with allusion to how the process is socially constructed by the methodology adopted. Juxtapositioned with this is a possible construct of what the ideal view should be so that responses for appropriate adaptation for sustainability can be nurtured.

The task in this section is to outline in increasing detail what a possible reconstruction of the ideal as a process of social construction should perhaps involve.

### **10.5.1 The analyses to be synthesized.**

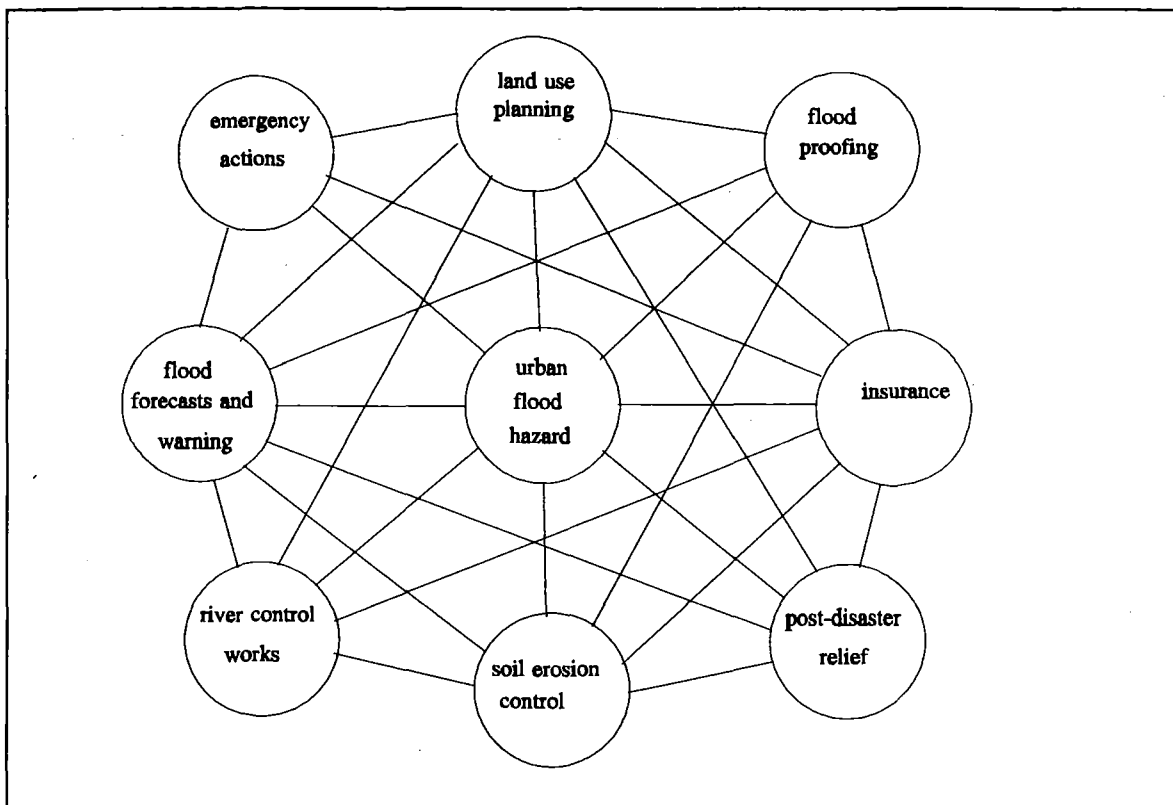
There are four distinct analyses, all developed from different perspectives on the situation, that need to be synthesized. The first three have all been fully developed theoretically from the literature and discussed and developed in previous chapters. The first part of the fourth is introduced and developed below.

- (a) The reflexive spheres as they apply to risk management (see Chapters 4,5 and 6).
- (b) The three feasible types of administration (see Chapter 6).
- (c) The aspects of engineering/management systems (see Chapter 4).
- (d) Three time scales and integration with the three SSM (see Chapter 9 and below).

The task is to synthesize them together coherently so that a floodplain management institution is created which is reflexive and open to allow adaptation, successful co-evolution and hence the achievement of sustainability. To do this requires the integration of the various discourses arising from the disciplines and publics involved. The GES system developed in Chapter 9 is suggested as the most appropriate way to do this. To recognise why this is the case the floodplain management system needs to be appreciated first.

## **10.6 THE FLOODPLAIN MANAGEMENT SYSTEM**

The cover of Ericksen (1986) gives an expression of the complexity involved in concern for urban floodplain management (see Figure 10.4, after Ericksen 1985; Figure 12.4). Unfortunately the book does not face the complexity portrayed on the cover. It is only used as an icon to indicate the dimensions and interactions. In an initial attempt to scope the complex issue a set of questions was given to Regional Councils: the first



**Figure 10.4;** Floodplain management complex.

used in the SSM of this research. Two complex models were drawn for consideration (see Appendix B). In a second questionnaire another complex system was asked to be considered and comment was requested (see Appendix C).

The first complex model (Figure B.1) considers the groups or actors involved in floodplain management. The second (Figure B.2) considers the factors and parameters needing to be considered in the evaluation of floodplain management plans and is based in a hard systems framework of considering parameters that are then to be aggregated in some way. Complex feedbacks occur in both, especially where environmental factors are addressed.

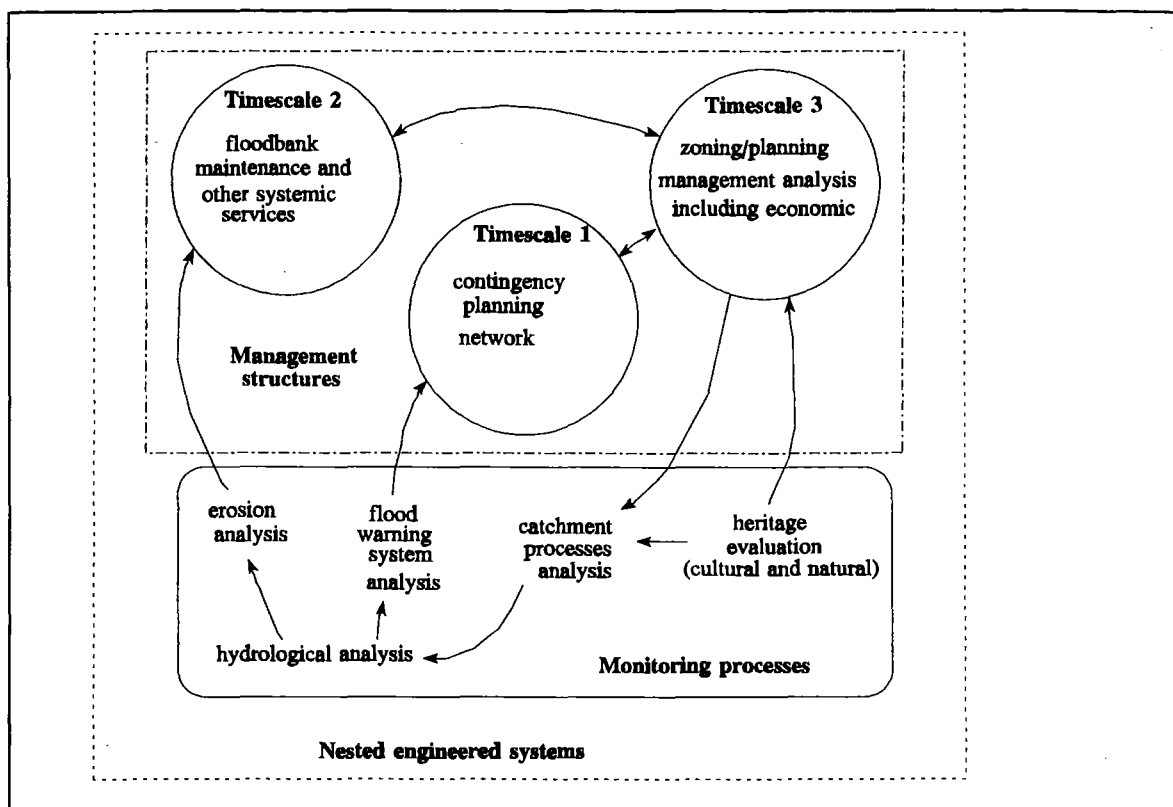
In the second questionnaire an updated version of what has to be taken into account in management plans was suggested as a second iteration of the SSM methodology used in the research (see Chapter 2). The results from the first questionnaire were recorded and qualitatively analyzed according to qualitative methodology from the phenomenological tradition in sociology (Hammersley 1989). It showed that the complex models were generally accepted but that they were not however seen as particularly helpful. The results of comments from the second questionnaire led to further emphasis of this difficult response, with however ever stronger questions being asked about the pertinence of the

complex model developed. This led to the realization that the problem is only partially one of defining the existing complex situation. This can only be the first step. It merely poses the problem to various degrees of accuracy. This is all that was achieved in the improvement of the second CM over the first.

What was missing was a realization that the systems being defined are socially constructed. Therefore the systems in their complexity are changeable and they are changed by how we decide to think about the system. Systems act as self-fulfilling prophecies. Once this was realized the responses from the Regional Councils made sense. It came to be recognized that for practical help, analysis must not only define the situation that is there. It must also point to how it can be reconstructed so that it can help socially construct a better situation and that these need not be complex. This has been attempted. The adequacy of the attempts at reconstruction as part of the wider SSM process of the research has yet to be tested however. A priori coherence is all that has been able to be achieved. It is beyond the time constraints of this PhD programme. However it is research which will be completed.

It was appreciation of systemic reflexivity which enabled an adequate insight into the dynamics involved so that deconstruction of the socially constructed complexity and a linear reconstruction could be carried out. This was generalized and is expressed in Figure 9.12 as part of a GES algorithm to be used with a SSM for resource management.

The challenge has been to start with the contextual reality explored through the questionnaires due to existing and past social construction of floodplain use, and to use the linear recursive model given in Figure 9.12 to make the process linear so that improvements can be carried out. Clarification of the processes and interactions is given in Figure 10.5. The three morphogenic engineered systems which have their own timescales for evolution within the adaptation process involve the three SSM and a GES explored in Figure 9.12. Figure 10.5 shows how the resulting three GES are required to be integrated to co-evolve with each other. What is not able to be indicated in Figure 10.5 is how the three GES are the SSM<sub>2</sub> as part of three sets of tri-SSM (SSM<sub>1</sub>, SSM<sub>2</sub> and SSM<sub>3</sub>) which are nested within each other. The faster processes are nested within the slower processes. Thus both contingency planning and maintenance of services are tri-SSM and nested within the tri-SSM and GES of planning. Hard system analyses making up the monitoring processes are nested within all nine SSM. The whole dynamic process of nested recursive tri-SSM processes can be understood as systemic reflexivity that needs to become conscious of itself through the individuation process of ontological growth of floodplain managers to perceive it and to take responsibility for their role in it. It is



**Figure 10.5;** Engineering systems of floodplain management.

complicated and hierarchical but not complex. It is linear in its recursive and hence indeterminate co-evolution. The monitoring processes involve modelling along with risk analysis as part of ESs. The monitoring determines deviance from norms defined by the ESs. It is technical monitoring where there are: hydrological analyses, erosion analyses, flood-warning system development, catchment processes analysis (geomorphology) and natural heritage (ecology). It involves public participation where there are cultural heritage concerns. Contingency planning systems involve the shortest time scales and quickest processes of adaptation. It is constrained in its ability to adapt by the state of zoning (planning). Also, however the zoning/planning is influenced by the structure for contingency planning. Adaptation in contingency plans will affect the adequacy of zoning/planning in total. Also floodbank maintenance as an example of systemic services is of the middle timescale and speed of processes of adaptation. Note that the various systemic services which are needed for floodplain management have been explored in Questionnaire 2 in Appendix C (see Figure C.3). Systemic services are constrained in their ability to adapt by zoning/planning, and likewise also influence what zoning/planning is adequate. Also they are constrained by changes in catchment processes. Zoning as the slowest process of adaption is constrained only by the catchment processes evolution

which occurs partly through how these changes affect the adaptation of contingency planning and maintenance of systemic services. But it is also influenced directly.

It is helpful to consider in some detail other types of responses to complexity which have been made in floodplain management so as to gain an appreciation of why this linear yet complicated and hierarchical approach is required.

### **10.6.1 Complexity**

The issue of complexity is central to floodplain management because the inability to recognize the significance of it is a characteristic of all existing methodology. To varying extents the issue has been swept under the carpet, either in ignorance by making assumptions that are not admitted to, or in pragmatism because something has to be done even though the difficulty is not resolved nor understood.

As already mentioned, what is missing is an understanding of the social construction of hazard and complexity and how these are related. Reflexivity to perceive social construction enabling the issue to be addressed is the process lacking in methodology to date. Reflexivity allows pro-active planning which institutionalizes moral freedom. Complexity is then seen as involving reactions (feedbacks) that are socially constructed which do not need to exist and break down cooperative social organization. It is however possible to deconstruct them and to reconstruct others which instead allow for the type of situations and management that is coherent and allows the required purpose (meta-ideals of sustainability, bio-diversity and social justice) through cooperation.

Complexity needs to be appreciated as failure in the social relations socially constructed by management. In not recognising this, failure in management involves accepting a degree of fatalism. To the extent this involves the use of technology it is what Ellul (1980) termed the 'technological system' acting as a 'cancer' that many are resigned into accepting that it cannot be stopped and is out of control. To cure the 'cancer' requires its source to be overcome which is the recognition of complexity through deconstruction, and to reconstruct it so that the community in its wisdom through contact with spirituality of the innermost sphere stays in control of what they create by taking responsibility for it. To do this requires deconstruction of the social constructions of incoherent management methodology causing complexity through ideologically obscuring what it is producing.

The dominant views in floodplain management are reviewed from this perspective below.

### 10.6.1.1 Complexity and the market ideology.

The market ideology does not explicitly define the complexity nor define ways to overcome or limit it. Rather it leaves the issue unaddressed and fits an abstract descriptive model that masks the existence of complexity, and then defines the consequences resulting normatively in an affirmative way as the good of efficiency that can be expected to result from complexity (see Chapter 8). Therefore such theories make an incoherent ideological self-rationale for the social institutions being implemented. If an explicit normative theory is developed it is not incoherent, but the values are still questionable because of the distribution of resources and sustainability of the market culture. A Marxian interpretation argues that it is because the values are so questionable that there is the ideological masking of them through the use of an incoherent descriptive interpretation (see Chapter 8). In consequence the market ideology socially constructs extreme complexity that is ideologically masked by a simple formal theory to justify what is done. The resulting competition is made a virtue of. The ideology is an expression of lack of reflexivity and individuation (ignorance rather than bad will) of those involved in promoting the market culture. It can be expected to result in conflict as 'eternal recurrence' of will to power unfolds as un-sustainability of the culture.

The ideology of the market would not be problematic if the consequences were only good as the ideology claims. It would not matter if complexity did not produce bad consequences, as well as the good of efficiency. As developed in Chapter 8 however, the reason the bad consequences occur is because as well as obscuring the complexity, the market ideology also promotes competition as the activity to produce the positive result of highest efficiency. In doing so it also promotes the negative consequences of negative freedom and the resulting domination and reactive responses leading to the non-respect of intrinsic values. There is a loss of openness to the sacred and hence the inspiration for reflexivity and ontological growth which overcomes ignorance and leads to wisdom.

But it is possible to have a market that is not competitive (as mentioned in Chapter 8) and so can cope with complexity by valuing it for the efficiency it brings, while avoiding the ideology of neo-classical economics. However this requires being able to define where and when it is appropriate to define a cooperative market. It cannot be implemented ideologically without second-order feedback informing about the limits of the appropriateness of a market institution. But if this does occur then the processes are understood and complexity is not masked, and unexpected hazards are not socially constructed, or if they are they are recognized as being socially constructed.

In floodplain management the negative consequences have expressed themselves as

an unstable development process that has increased damage - the flood damage paradox mentioned in previous chapters. Further, the extent of the failure of the market has led to counter-adaptive political consequences as can be expected, and introduced above. In Aotearoa/New Zealand national relief was a necessity, with subsidies required to pay for the construction of projects with high enough benefit/cost ratios so as to create market conditions for development. This became too expensive however and so reliance on the market ideology was forced to change. There has been a move to try to regionalize or individualize the investment to create the market conditions for development in Aotearoa/New Zealand (e.g. Ackroyd et al. 1987). With the Resource Management Act (1991) (RMA) a regional approach has taken precedence with market concerns for efficiency placed within a context of other goals as well.

Never-the-less the market ideology still has a lot of appeal politically because of the formal simplicity of the methodology, and hence cheapness in application, thus making it tempting to apply indiscriminately and in denial of second-order feedbacks in the system. Those still lobbying for it are those benefitting in the short term, i.e. those who dominate in society at present - the business groups (Munn 1991). However even with the RMA, because of the cost involved in legal services and expert witnesses, there is a bias toward business groups allowing them to dominate (Whiting 1995).

In an opposite direction, development of floodplain methodology has also been developed to apply implicit consent techniques of willingness to pay to extend even further the complexity resulting from the market ideology (Green et al. 1983, Tunstall et al. 1988, Green et al. 1989 and Young 1990). As yet however these have had little effect on floodplain management in Aotearoa/New Zealand and have been resisted in favour of ecologically and integrated approaches.

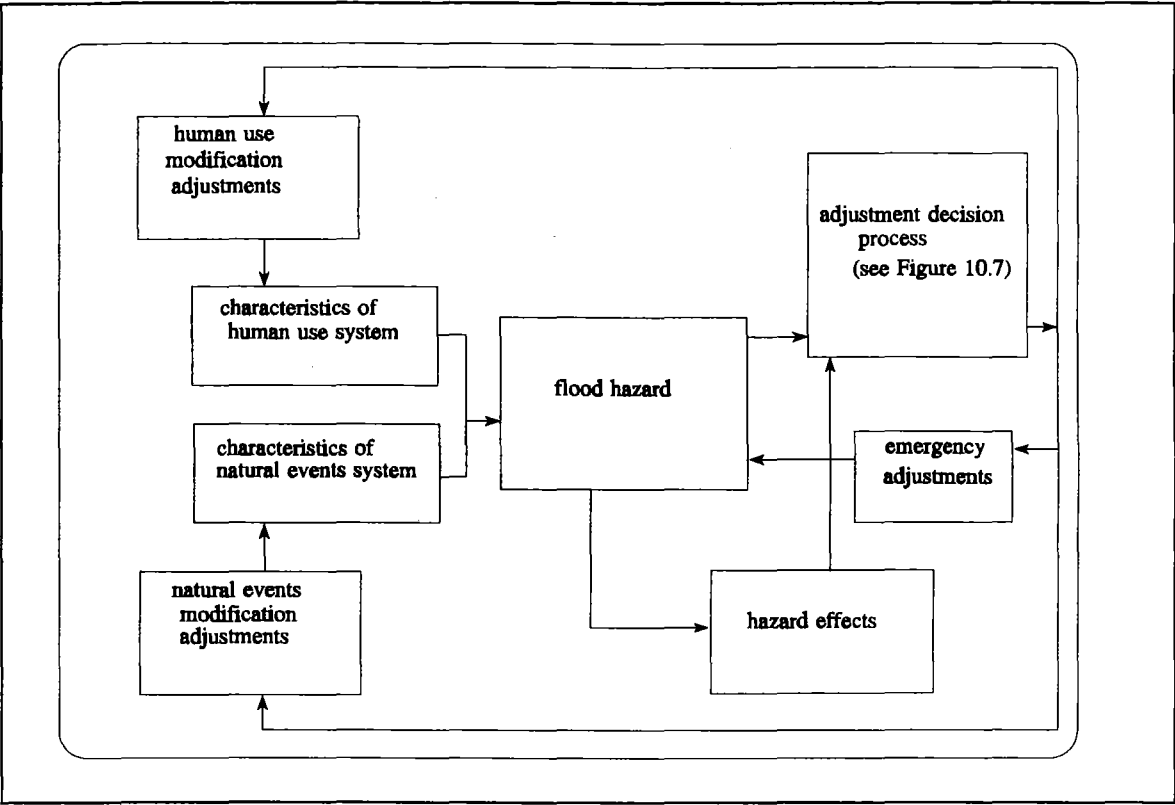
#### **10.6.1.2 Complexity and the ecological model.**

The main theoretical development in floodplain management methodology, and the closest thing to a tradition, is that of the emergence of the ecological model. Even though it does not acknowledge the social construction of the floodplain management system, it does however recognise the complexity of the situation, especially in terms of the co-evolution occurring.

Complexity is recognized though still masked as in the market model. But it is not made a virtue of. It is recognized but not understood. So an approach to try to cope with it is given but inadequately because of the implicit use of an ideology due to lack of reflexivity.



The theory of adaptation held is non-reflexive and so not able to give pro-active guidelines as to how floodplain methodology can improve. Rather the process is reactive in the application of methodological individualism. The adaptation model used is outlined in Figure 10.6 (after Ericksen 1986; Figure 1.2). The development of the decision-making

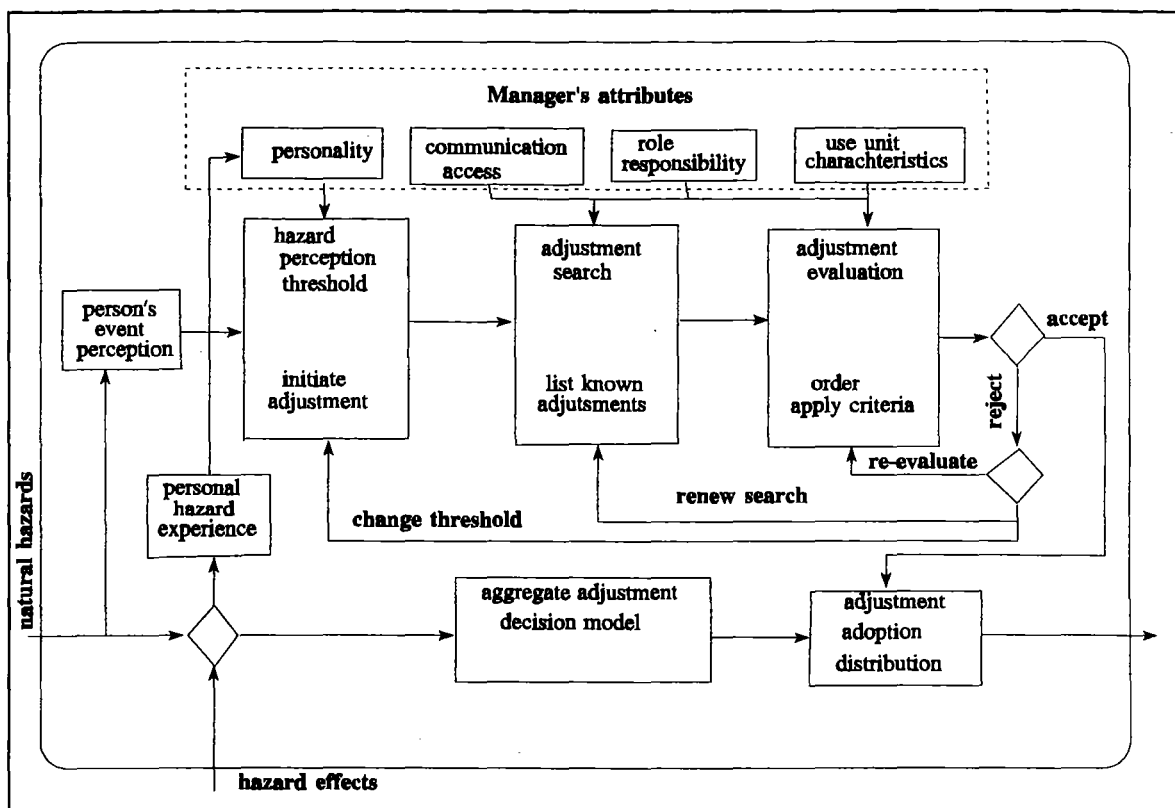


**Figure 10.6;** Adjustment to flood process.

theory along the lines of methodological individualism is an expression of behavioural theory (e.g. Ericksen 1986) (see Figure 10.7 after Ericksen 1986; Figure 1.3).

In effect the social dynamics being left to operate are not much different to those which the market ideology encourages. What is significantly different however is how the ecological model sees the importance of technical information whereas in the market model it remains an externality. But neither is the ecological model able to integrate technical information so as to pro-actively improve the situation because the underlying dynamics of social construction within the reflexive spheres is not appreciated. Thus it does not allow an understanding of how dialogue with the public by technical experts can change the management plan, and hence the social construction of the resulting consequences.

Being coupled with methodological individualism means that the structural relationships that are complex are not able to be changed in any way other than by



**Figure 10.7;** Adjustment decision process.

dictatorship by the technical experts. Figure 10.7 privileges the manager's attributes for decision-making. Adaptation is interpreted as only being reactive as individuals responses that have bounded rationality (Slovic et al. 1982) that are presumed to form a collective social reality within a market that conflates individual and social rationality (see Chapter 9).

So complexity is likewise accepted fatalistically as something unavoidable because knowledge concerning the social construction of it is not known. Technical analysis and authority are seen to have the role to limit the mistakes of individuals and society rather than to collectively in moral freedom with all of society create the culture, nature and sustainable hazard.

The technical experts are assumed to have authority but there is no argument given for why technical expertise should be centralized in its authority. A SAOR type model (see Chapter 6) is effectively implemented but no appeal is made to it to justify the approach. Not acknowledging the assumptions made means that the ecological model is not reflexive enough to change to develop a deeper understanding. This is shown clearly by Burton et al. (1978) who criticised traditional approaches toward natural hazards based on spirituality and trust. It was labelled as unsophisticated. The opposite conclusion has

been made in this research through the attempt to understand the causes of hazards. In short, it may be 'unsophisticated' in the very culturally specific meaning of the term, but it can be expected to be successful because its simplicity and wisdom can successfully overcome and avoid complexity and fatalism while being also able to adapt and hence maintain sustainability.

For example the Maori traditionally applied the concept of *muru* for floodplain management (Patterson 1992). *Muru* is the institutionalisation of second-order feedback which comes from the environment. When a person (family's settlement) was inundated by a flood the wider society destroyed what was remaining of the family's settlement in punishment for creating the situation (of a hazard) which the god of the river found unacceptable. Disrespect of the river is how the wider society interprets peoples' creation of hazard which leaves them flooded. As long as people have the choice of where they do settle (unlike in contemporary Aotearoa/New Zealand because of the culture of private property held since European colonization) this can be expected to be an effective way to avoid social construction of hazard. The institution of feedback is correct in comparison to the use of subsidies to create the hazards and to blame God for anything bad which happens, while continuing to try to control it in battle (with God?)

Burton et al. (1978) in their ecological approach assume a development ethic that all cultures should and will (making the naturalistic fallacy and introducing fatalism) follow the Western Enlightenment cultural evolution.

#### **10.6.1.3 Complexity and integrated management.**

As mentioned above, there is much literature on this approach for resource management. However it has not been applied widely in floodplain management. An exception is Griffiths et al. (1991) in the Canterbury Regional Council floodplain management plan for the Waimakariri floodplain. Unlike users of the ecological model, Griffiths' integrated management approach does not have an evolutionary model for adaptation with which to attempt to describe the process of adaptation. This works to his advantage however as the lack of depth of the SAOR-type basis is not present to obscure the complexity present. Consequently all assumptions are made explicitly and problematic ones are attempted to be addressed. This leaves the possibility for reflexive consideration of what needs to be critiqued.

Griffiths points to Arrow's paradox and the inability of methodological individualism to come to a coherent non-dictatorial solution (see Chapter 8 and 9). However instead of questioning the use of methodological individualism, an open explicit dictatorial approach

is adopted - albeit one which attempts to be practical and as democratic as possible. A sophisticated attempt to implement a type of Hyper-game theory has been made (Griffiths 1995). Without an obscuring ideology or inadequate adaptation model the difficulties with the choice of a dictatorial position leaves open the possibility of further reflexive consideration of how to be more proactive, and to question the assumption of methodological individualism. However only if the assumption of methodological individualism is questioned and rejected can the social construction of complexity be expected to be fully addressed. Griffiths does not do this but in keeping with the rigour of his analysis the questionable consequences of complexity which are not understood are never-the-less attempted to be resolved through the use of the originally developed version of hyper-game theory for conflict resolution.

As with the ecological model, technical information is recognized as valuable and attempts are made to include it, but this is done necessarily dictatorially. The inadequacy of market ordering of social consequence is recognised (Griffiths 1990) and attempts to be pro-active with community involvement are made. However they have not always been successful unless interactive procedures to produce a communication situation are provided by the use of a professional mediator.

In consequence a benign dictatorial position was taken whereby consulting with the public as to alternatives that they can choose from was carried out. But in crucial periods of debate/conflict, mediation to 'expose hidden agendas' so as to create a better communication situation have been required, requiring council authority to be relinquished to a large extent.

Thus complexity is still considered to be inevitable because the social construction of it is not explicitly recognized. However in situations of extreme problems caused by the non-addressing of the existence of complex social structures and interactions, a technique to deconstruct and locally reconstruct the social structures is employed out of necessity.

#### **10.6.1.4 Approaches to complexity by the Regional Councils.**

Overall trends of how complexity has been faced, come in three main forms. They underly the market, ecological and integrated management methodologies. They are arguably however all expressions of 'theories-in-use' (Argyris 1982 and 1988) in the attempt to socially integrate because attempts to seek to fulfil ideals and to be coherent have not been successful or are perceived to be too difficult to implement.

Paul (1991) of the Wellington Regional Council considered the process at a

crossroads at that time, with two possible courses to follow. One way was to seek to further the market approach according to the research program of Parker et al. (1987). The other way is to develop the approach suggested by integrated management which emphasizes the importance of public participation; Paul cited Blackford (1990c). Paul was however critical of the public participation approach because of experience with consultants on public participation procedures whom he considered were impractical. He argued that they expected too much immediate understanding from the participants, including technical experts. Specifically, he found it impossible to outline the values that they the managers had, which appeared to him from what he was hearing, was the starting point for the public participation process. This critique of the need for managerial reflexivity is indicative of the general difficulty there is in accepting the need to recognize the existence of different discourses if a practical approach to public participation is to be achieved.

As already mentioned, Griffiths with the Canterbury regional Council also has had difficulty with the public participation approach because the public were not able to be proactive in directing the technical experts as to what the issues are. But he has begun to explore the dynamics at work through embracing professional mediation. Koutsos (1991) of the Hawke's bay Regional Council also expressed sentiments of disappointment in the public's participation, but held it never-the-less to be a necessary ideal.

From between these two unsatisfactory options, a third comes in practice to be an approach commonly carried out. It is the legalistic approach of fulfilling the statutory obligations which can be interpreted as a means to cope with the complexity. The second questionnaire in this research got sharp replies from the Hawke's Bay Regional Council (post-Koutsos era) and the Otago Regional Council saying in effect that the suggested scheme did not directly refer to the statutory obligations, and at the same time considered it to be not straightforward enough.

The development of description of the complexity that the second questionnaire involved was not recognized as necessary. It was assumed that the best solution is to be found by accepting that statutory obligations give the appropriate way to approach floodplain management irrespective of the situation. If they are correct then engineering and resource management as disciplines are merely subsets of the discipline of law. It makes more sense however to interpret the replies as expressions of 'theories-in-use' indicating responses avoiding facing up to the complex situation. Social integration involving not questioning assumptions (not being reflexive) and ignoring second-order feedback becomes the easiest option in the short term, and as conflicts arise through such

an expression of insecurity. That this appears to be the better interpretation was vindicated in some respects by the Waikato Regional Council, which bases its floodplain management strategy on the ecological model. They replied in contrast to Hawke's Bay and Otago, that the complex situation outlined was realistic. Even though the ecological model can be criticised, it at least involves the attempt to face the reality of the situation and recognizes the difficulty and complexity of the existing situation in Western societies.

It is commonly concluded that instead of facing the reality, and attempting to gain a coherent understanding, statutory processes can be used to define what should be done. This is however an abuse of law (see Chapter 9). In effect the existing complexity is reproduced and no attempt is made to improve the situation. The problems that arise because of the complexity that is not recognized, nor appreciated for what it is, are faced instead through the adversarial situation of legal proceedings without prior reflection on the issue. Technical and ethical issues are effectively treated as externalities (to the legal system). This is further exacerbated by technical information entering into the situation as expression of 'professional' expert witnesses where the pedigree of the truth is able to be abused.

Sphere 3, incorporating individual integrity and conflict, which is indicating important second-order feedback is not treated as a source of information to point to what needs to be considered to improve the situation. Rather power is used to enforce a particular situation in face of the conflict in an attempt to close the system and continue in the existing counter-adaptive trajectory. It can be recognized as counter-adaptive because conflict indicates that sphere 3 is providing second-order feedback which is not yet integrated and needs to be used to inform the cultural evolution. Power to enforce a decision and unstable system state is relied upon rather than the development of trust and understanding through dialogue to renormalise and achieve flexibility in the system. It has an ideology which does not rely on learning. The role of information in structuring systems is not adequately appreciated.

However there were attempts to gain coherent understanding of the situation. Two different views were expressed. Koutsos (1991) saw a 'contract' between use of the floodplain and Nature. This concept was used to underpin an understanding of sustainability. Sustainability was interpreted in terms of the continued use of resources that the floodplain provides for humans. Hall (1991') on the other hand saw a 'symbiotic' relationship between the human life on the floodplain and the other life on the floodplain. His view was much developed through his involvement as an 'investigations engineer' for the Canterbury Regional Council involved with Maori iwi. Hall's approach allows for the

integration of people and the environment and thus allows a deep coherence to be found through the process of reconstruction that seeks to renormalise, humans involvement in ecosystems. His approach seeks to do this by allowing the cultural value of spirituality to be integrated into analysis. Hall also voiced the opinion that technical experts with the authority need to act as 'elders' - wise and responsible servants who are open to dialogue. Hall's view is consonant with the view developed by this research, i.e. that wisdom can be gained and this gives a responsibility for social construction of the worlds for others which nurture their learning and gaining of wisdom also which does not do violence to natural freedom and the possibility of cooperation through moral freedom.

#### **10.6.1.5 The requirements for an adequate approach to complexity.**

Firstly complexity has to be recognized. This requires the deconstruction of ideologies which legitimize the consequences of complexity and mask the complexity with social constructions so as to continue it. The market ideology and to an extent the ecological model need to be critiqued in this way. This needs to be done in a rigorous intellectual way helped by sociologists within a multi-disciplinary team. It requires to be reflexively guided by conflict in sphere 3 as this indicates what needs to be faced to critique and to understand the dynamics of the complex situation, including ideology/structural power. Once the social construction of it is perceived, pro-active reconstruction carried out with moral freedom and inspired by creative vision can occur.

The process is then pro-active in the attempt to create a coherent reconstruction to socially construct a non-complex situation which enables the culture to be adequately adapted to the environment. A SSM<sub>1</sub> which draws out the publics to express what their interests and goals are to form RDs develops into open discussion. The systemic reflexivity giving rise to conflict can then be attempted to be mediated so that evolution of the social systems making up floodplain management can occur in an attempt to bring about renormalized adaptation. Thus community development can occur. Also to the extent advocates for non-humans are present, ecosystem development can also occur. Its institution gives the possibility of hope through encouragement of vision. Fatalism is avoided, though immediate success is not assured. The aim is long-term and incremental but aims to maintain and increase stability through increasing flexibility.

Community development was the acknowledged aim of Griffiths at the Canterbury Regional Council but it was not able to be formalized in this way because of the lack of 'depth' in the analysis through not recognizing the social construction of the situation.

### 10.6.2 Linear ESs in a nesting of GESs for integrated floodplain management.

Linear processes have goals with chains of events to achieve them. In management the chains of events are sequences of decisions. In an ES it is a sequence of rules. The first step is to determine the goals. These are produced by questions that management need to allow to be asked. They are raised from the three nested sets of  $SSM_3$  and  $SSM_1$ . For floodplain management they are obtained from Figure 10.5 which is itself the end result of the SSM process involved when exploring the situation with the Regional Councils in Aotearoa/New Zealand. The pertinent questions are:

1. Where/what are the floodplain zones?
2. What level of protection is to be considered?
3. What catchment use changes are planned?
4. What type of floodbank maintenance is to be used?
5. What type of floodwarning and emergency operations are to be used?
6. What rates to charge?

However asking these questions brings into question other issues. Thus integrated management *naturally* arises out of conversation which explores relevant issues without specific discourse constraints. It can be attempted to be constrained into a specific discourse by claiming that floodplain management is within certain limits as some legalistic practitioners suggested. But to do so does not allow systemic reflexivity to be individuated thus allowing a truly proactive and holistic approach to be developed by being open to second-order feedback.

Therefore it can be expected that applying the postmodern social constructionist views developed in previous chapters would help lead to the emergence through conversation of an appropriate integrated management. What is required is to have the nested pairs of  $SSM_1$  and  $SSM_3$  institutions in place to help mediate it, and with nested  $SSM_2$  to integrate them.

Part of the conversation *naturally* leads on to other resource issues; e.g. water quality, natural and cultural heritage, social justice and utility systems or 'essential' services (e.g. transport, electricity and telecommunication). These extensions were explored in the questionnaires and some recognition given by some practitioners that they are all involved in the issue. An example of how they can be integrated is given in the example of Chapter 9 on water quality. The example raises the issues of future development plans, flood mitigation, affect on utility systems and cultural heritage. To define fuzzy optimific options linguistically defined requires statements about these issues as well to be included.



The GES methodology as a type of machine learning which was developed there and illustrated by the example is general and so is capable of incorporating these other issues. What is required is to allow the scope of integrated management to be socially constructed through the conversations so the full scope of the issues can be addressed in the attempt to 'listen' to all pertinent second-order feedback. It does never-the-less raise issues for institutions, e.g. Regional Councils in Aotearoa/New Zealand, which operate under statutes which define the system boundaries. But if legalism is avoided this can be overcome. This is developed in Section 10.6.4 in relation to the Resource Management Act of 1991 (RMA).

#### **10.6.2.1 Structure of a linear ES.**

The social construction of the scope of integrated management results in defining foci of interest. The second set of questions asked of Regional Councils addressed these issues. As already mentioned there was a legalistic response by some who wanted to use statutes to define what was integrated floodplain management. Other responses however added a few details and accepted that the foci covered the issues that do arise. Therefore the outline (Figure C.3) produced in the second set of questions can be accepted as an adequate first attempt at developing a CM, albeit in a complex way. Figure 10.5 is a further development. The next step is to structure the parts so that it can be implemented within nested GESs. It has to be made into the recursive linearity given by Figure 9.12 and the types of analyses forming the hierarchy of concepts given in Figure 9.7.

Firstly the relationship of the foci to the reflexive spheres needs to be clarified. From Chapter 9 it is modelled that sphere 1 needs form goals that result in sphere 2 needs and that sphere 1 wants do not. The distinction defines what adaptation is renormalizing the system. Clarification of sphere 1 needs and wants is a process of being open to second-order feedbacks directing integration at the sphere 2 levels of human community and ecosystem, as well as personal integrity.

The foci of integrated management form the needs in sphere 2, i.e. systems. They include the reconstructed economic systems that enable cooperation to produce reciprocity to justly distribute resources to all groups in society (see Chapter 8); reconstructed ecological systems (sometimes under the title of natural heritage); cultural heritage to reflexively nurture coherent mythology/ideology/worlds; and service systems of society.

Examples of wants that should not be attempted to be defined as systems are maximization of profit, and recreation when it is an expression of commodification. Attempts at their maximization is the approach of neo-classical economic theory and is

counter-adaptive and unsustainable (see Chapter 8).

Sphere 1 needs are technical goals and rules in ES associated with achieving sphere 2 needs. Chapter 8 outlines such rules and the technical analysis required to evaluate them for achievement of appropriate economic systems. They form a hierarchy of linear chains and so fulfil the requirement of linearity to avoid complexity. Chapter 7 discusses the goals and rules that occur in all systems involving hydrology and develops the technical analyses required to consider data associated with such systems, including flood warning systems and bank erosion included in Figure 10.5.

Chapters 5 and 6 discuss what features are required of technical analysis so that the ethical principle of precaution and non-technocracy is implemented in evaluation of goals and rules. They also develop how rigorous definition of uncertainty and imprecision can be carried out to assure that the social construction of goals is free of objectivist ideology.

What the sphere 1 needs are that need to be defined are not specifically addressed. However the analytical techniques developed in Chapter 5 and 6 and to the extent hydrology is involved, the methodology associated with analysis and evaluation has been completed. Specific development of ESs as part of nested GESs integrating floodplain management is research yet to be carried out. What is developed in the rest of the Chapter is how nested GESs can be used generally within the floodplain management process.

### **10.6.3 Implementation of GESs in integrated floodplain management.**

The first stage involves the attempt to define coherent goals in sphere 2 which is carried out through a pro-active process of dialogue enabling individuation of systemic reflexivity so that sphere 3 situations of escalating conflict are avoided, by allowing renormalization to occur before ecological and/or social system breakdown occurs.

SSM<sub>3</sub> though institutionally recognizing sphere 3 and thus enabling second-order feedback to be integrated, may require the use of mediation to help in the process. Such situations can easily occur over ideological systems of cultural heritage which are symbolic and are hence more prone to be contradictory between groups and cultures. It may require some hierarchy of prominence to be given. For example in Aotearoa/New Zealand indigenous Maori cultural heritage has privilege. After that heritage is evaluated according to age. However public's icons giving a sense of place are also of importance for social will and are not necessarily related to official heritage (Whittle 1993). It is doubtful whether an official landscape ideology is likely to work. However symbolic ideology or myths are art that arose out of the personal in the ethical relation and so

personal contact between the people concerned can be expected to help recreate a *living landscape* for diverse groups and cultures.

Another debate that can be expected to occur is that which occurs between groups who are seeking their self-interest in an unbalanced way through the use of ideological coercion for short-term adaptive advantage. The result is counter-adaptive for personal, human community and ecosystem integrity. Their resulting alienation and insecurity are expressed as attempts to control and dominate in the pervasive positive first-order feedback. As already mentioned, the use of mediation has been found to be helpful to expose the hidden agendas of such groups.

When agreement is made on these issues  $SSM_3$  ceases though it can and needs to be allowed to reappear if and when necessary. To deny the possibility is to set in motion systemic reflexivity which will result in the assertion of renormalization in more traumatic ways because it is not an expression of individuation and ontological growth. However when  $SSM_3$  is not needed at any particular moment in the nested recursive processes, functional coherence of sphere 2 and a potentially appropriate engineered system has been contingently discovered and defined by the set of goals making up the CM.

#### **10.6.3.1 Structure of a coherent sphere 2 system for integrated floodplain management.**

The structure of a coherent system is dependent on the particular engineered systems being able to act together functionally as a whole to help maintain human communities, ecosystems. This will occur if the system as a whole can tolerate variance within each engineered system. The variance can be appreciated by analysing how the modelling of engineered systems produces fuzzy results. They can be interpreted as expected variation of actual occurrences of processes that are repeated. Also the goals that the engineered system is aimed to achieve are fuzzy. In other words, the imprecision arises because of openness in all systems being analyzed and the imprecision in expression of public definition of goals.

However when the uncertainty and imprecision are explicitly acknowledged through application of calculus able to appreciate it, that has been developed in previous chapters, each particular engineered system and the overall one can be constructed. The achievement of goals according to an appropriate level of risk can be modelled because the process is linear even though they are recursive and indeterminate and the three engineered systems making up the whole are co-evolving with each other.

#### **10.6.3.1.1 Risk and resilience of engineered systems.**

Technical risk is not appropriate because the domain of a large number of events able to be considered through the use of a random generator metaphor is not present. Engineered systems emerge in sphere 2 and so their overall appreciation requires to be by an organismic metaphor. Risk has to therefore be analyzed according to the possibility and necessity of the occurrence of individual events. This has been intuitively known in floodplain management through the use of the Return Period as a criterion for design of flood protection (see Chapter 7). It has been recognised that a principle for design of floodplain protection is to keep the Return Period value constant through the system. This is for ethical reasons as well as for design efficiency. Contingency planning takes a step further and aims to deliberately have a weak function in the system which when it fails sets into motion the adaptation into a new plan that is functional as a whole for that level of risk even though it will produce higher damage. Trust and cooperation is maintained and so the system is sustained. That this has only been intuitively recognised and not formally understood through the use of, or an equivalent understanding of, the reflexive spheres can be interpreted to be why, as tools of analysis improved, there was a move to attempt to carry out Risk CBA which models the situation with a random generator metaphor, instead of continuing with the Return Period criterion. Also the way the Return Period has been used has not taken into account the imprecision of the risk value (see Chapter 7). In other words the system justification of it which is coherent - to maintain functionality and flexibility - is not made because attempts to ensure that the operation of the whole system does operate as planned requires an acknowledgment of the imprecision in analysis and hence actual risk associated with the achievement of the required goals.

What is required is that the imprecision in analyses be incorporated so that the measures of risk be possibility and necessity valuations associated with statements in an ES which apply the precautionary principle, and monitoring if new technology is being implemented. Contingency planning then involves a multistage series of rules in an ES. An example of an archetypical situation for floodplain management is given in Section 10.7. Functionality is sought for each stage, remembering that what is functional is open to redefinition from sphere 3 through the co-evolution of the various engineered systems operating at different process speeds with the nested tri-SSM. The resilience of an engineered system at any particular time can be affected by change in the systems making up the technical analyses of sphere 1 and by inclusion of other components into the system that change the acceptable risk, e.g. the implementation of a flood warning system which enables higher uncertainty to be handled by increasing the scope for faster processes in

contingency planning.

The rules for an ES developed in Chapter 8 define some of the acceptable boundaries for the economic system which forms an integral part of the engineered system which has the slowest process (see Figure 10.5). In this way appropriate economic modelling is carried out rather than the use of CBA within neo-classical theory which fails to distinguish the spheres' reflexive interaction.

At any moment in the co-evolution there can not be expected to be only one plausible option for the various engineered systems that are co-evolving. To decide what is the optimum one requires the use of a GES as a  $SSM_2$  as developed in Chapter 9 which uses meta-rules derived from  $SSM_1$  and  $SSM_3$  as second-order feedback.

### **10.6.3.2 Optimisation of the possibly coherent engineered systems.**

The possible coherent engineered systems occurring in sphere 2 are comprised of sets of management options (MO) which operationalize the construction of the sphere 2 engineered systems (see Chapter 9).

The distinction between engineered systems and MOs is relative however. Both are social constructions that are means to achieve higher goals defined by meta-values so as to promote integration as functioning human communities and ecosystems. What distinguishes between them is the relative need for incremental evolution from the existing socially constructed engineered systems. Engineered systems are defined where there is adaptation occurring without loss of identity. Here the use of speed of processes has been used to distinguish between different types of engineered systems needing to co-evolve with environmentally directed processes. Whatever combinations of specific MOs which may be plausible at any particular moment some set is required to be adaptable so as to create an acceptable hazard with the environmental processes occurring at the different speeds. Also it cannot be assumed that for all of the future the MOs within integrated tri-GES will be found in the domain of the possible combinations of MOs defined at present. For example new technology may introduce new MOs. Also new engineered systems may also emerge and may start out as new MOs. For example the maintenance of a telephone system as a necessary engineered system only began to be socially constructed (as a MO) when the technology of the telephone came into place. Then only as it came to be found to form an important functional role in community relationships did it come to be seen as an essential service.

An example that is at present ambiguous and can be taken as either a MO or an engineered system is a flood warning system. Reliable and comprehensive systems are

only a recent technology and are still being developed. See Chapter 7 for developments which allow it to be integrated within ESs. Their implementation is likely to evolve in prominence once they are operating and flood proofing that requires some warning for its full worth to be manifest is further developed as well.

In the dialogue of SSM<sub>3</sub>, explanation from technical experts and the proven capability of MOs (e.g. flood warning) may lead to them gaining high pertinence for the whole integrated engineering system and hence come to be considered to be engineered systems in their own way. The overall system being socially constructed is open and co-evolving through the pertinence of various MO forming traces of significance.

Working from what are socially constructed as possible coherent engineered systems, possible MOs to operationalize them can be explored. This should not be done with prejudice as mentioned in Chapter 9. For all publics to have their possible MOs taken seriously and analyzed (even if the result is only to inform their creators of their infeasibility) helps develop trust and avoid entry into sphere 3 as conflict rather than creativity. Brainstorming through SSM<sub>1</sub> is appropriate as it is explicitly open-ended.

In developing a possible MO its ability to fulfil both the needs and wants of sphere 1 are required to be considered (see Chapter 9). They also need to be decomposed into management actions that form the components that are incorporated into technical analyses (see Chapter 9).

Step 1 in the algorithm for the GES developed in Chapter 9 defines constraints on MOs. As well as the constraints given by the engineered systems goals, an acceptable overall risk level is applied as a constraint. Note that this process is itself one which may require considerable analysis.

Once the constraints and plausible MOs have been determined the GES algorithm outlined in Chapter 9 can be implemented for whatever scope the various engineered systems comprising integrated floodplain management have been found to be required to cover. The outputs are linguistic statements referring to all defined needs and wants that enter into SSM<sub>1</sub> (and SSM<sub>3</sub> if necessary) for consideration of what are the appropriate plans for the various engineered systems.

Implementation of meta-rules to guide decisions about what are the better ones can likewise be carried out using fuzzy logic. Final contingent approval for the best however requires openness to SSM<sub>1</sub> and SSM<sub>3</sub>.

#### **10.6.4 Application under the RMA.**

If such GES and nested SSM processes are used by Regional Councils in Aotearoa/New Zealand they have to be compatible with the requirements of the RMA. The RMA has a precisely defined set of procedures for plans which cover floodplain management and involve court hearings. These are yet to be tested out, but it is unlikely that the adversarial procedures and strict and narrow prescribed time horizons for the procedures will allow such processes to be implemented.

However there is room and positive encouragement for pre-plan and submission interaction with publics (Sheilds 1993). It is in this stage that such a process attempting to avert sphere 3 conflict and to rigorously move toward sustainability is very useful. Sphere 3 as conflict can then be avoided and the costly legal hearing stage may be able to be minimized and also made more just. The inappropriate use of expert witnesses idealizing data to support claims of interest groups will be less likely to stand if more rigorous analysis that is not idealizing and has already been carried out to the satisfaction of the publics can be presented by the councils.

But even if the pre-plan interaction is successful integrated management which is to successfully achieve sustainability requires constant openness to adaptation and the various engineered systems are required to continue to co-evolve. Therefore the legally binding nature of plans may be a hindrance because it may make it more difficult to adapt as required. For the legally binding nature of plans given by the RMA to be helpful requires that the plan be only concerned with meta-plans which help create the possibility of the monitoring that is required and the continual adaptation of the engineered systems making up the whole system. This will also take away the possibility of legalism as an option for managers.

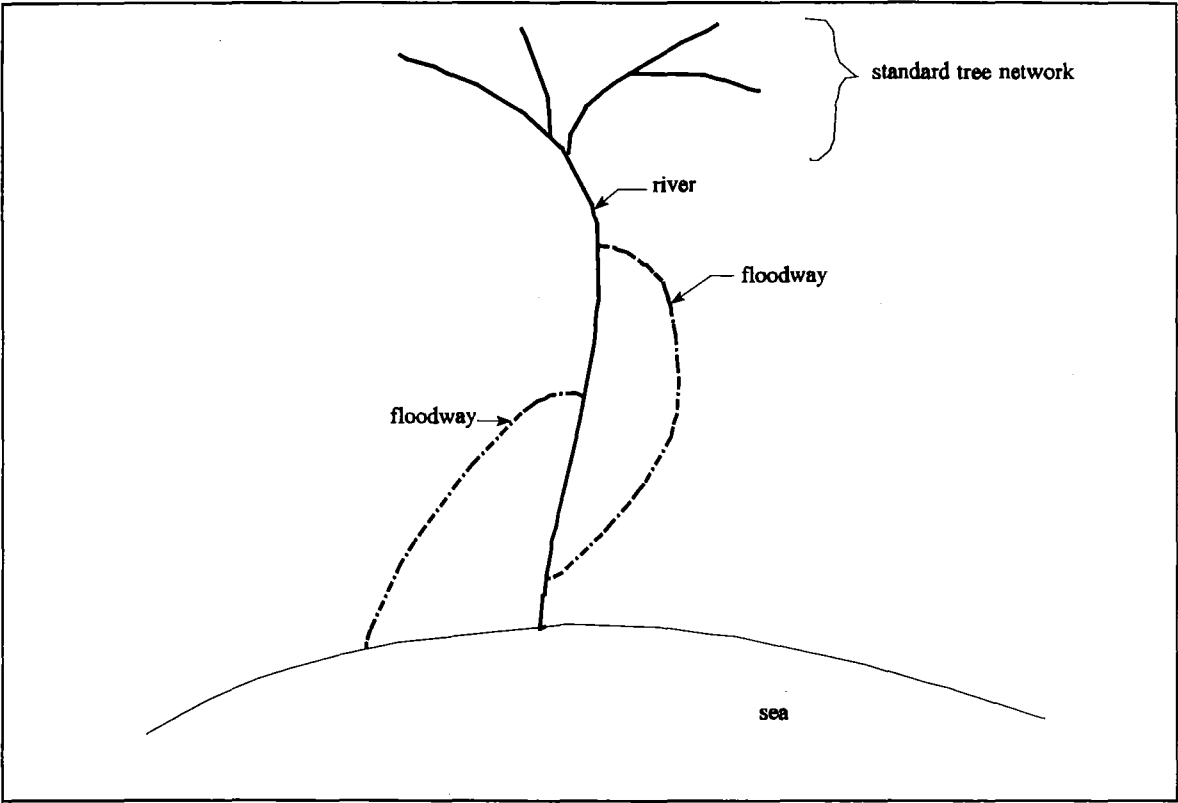
### **10.7 AN EXAMPLE APPLICATION OF INTEGRATED FLOODPLAIN MANAGEMENT**

Consider the situation also used as an example in Chapter 8 (see Figure 8.6). The first thing to consider is the analysis of risk as this forms part of the determination of constraints on possible MOs. Here the effect MOs have on the economic system are considered. They are given by the rules defined in Chapter 8. If an economic entity covers more than one zone then the values involved (e.g. damage) have to be aggregated. However, because this is the sum of magnitude over a period it cannot be given by the arithmetic sum before simply applying the rules. It has to be given by the sum of the magnitudes given the same uncertainty. However if TFM is used to create standard truth,

with the statements defined by possibility functions, they are the same. Note also that this applies the precautionary principle because the Central Limit Theorem would allow some greater precision to the extent that different probability functions can be expected to derive from the same distribution.

If the analysis is framed another way (see Chapter 8) and the fuzzy uncertainty as a consequence of fuzzily defined limits to the range pertaining to each zone is analyzed, the aggregate fuzzy uncertainty is given by a conjunction of them (see Chapter 9).

The use of floodways as part of a multi-stage social construction of hazard can form part of a network as analyzed by the GES algorithm. However unlike the 'tree' networks of standard river networks the use of floodways has branching alternative streams



**Figure 10.8;** River/floodway network.

and even loops (see Figure 10.9). Such situations are still able to be analyzed by the algorithm, but the MOs form structural patterns that put further constraints on what are viable MOs and requires that they be considered as sets rather than individually. In effect MOs in relation to sets of MO become like MAs in relation to MOs.

This requirement may also occur where floodways are not an option if certain engineered system requirements have requirements transcending (sub)catchment boundaries. Main examples are the use of reforestation of upper catchments and work to



limit erosion of channels. The hydrological modelling developed in Chapter 7 can be implemented and used to enable these two options along with the use of floodways to be rigorously considered with all their uncertainty and imprecision.

## **10.8 CONCLUSION**

A floodplain management methodology that incorporates the best of the existing methodologies, i.e. that of ecological modelling and integrated management, is possible. Also the need to fulfil the requirement of linearity can be achieved by appreciation of the social construction of hazards and risk and through the use of nested GES within nested SSM. It gives a decision model that best implements known theory and is flexible enough to provide a form for conversation involving the many discourses arising in interdisciplinary analysis and public participation, and concern for differing processes of the environment involving different time scales.

The required features for such an application of a GES have been explored and the relevance of specific elements that have been reviewed and developed in earlier chapters are tied into the methodology.

What remains to be done is a thorough development of the expected significant ESs required to cover the engineered systems indicated as relevant at the moment. Even though this is inherently contingent and regionally specific, the clarification of general ESs will enable the next step of software development, thus enabling the methodology's use and application by Regional Councils. This next step will require to be comprehensive long-term and to have its own SSM.

## Conclusion

Through participation in the wider environmental/social issue of seeking sustainability, floodplain management is in the midst of debate about how to carry out integrated management that fulfils ethical concerns. One of the most significant conclusions from this research is that there is a fatalistic view claiming that the implementation of ethics is unrealistic and that this view is the product of existing metaphysical assumptions that are embodied in social institutions of elite technical expertise, of which the engineering profession is one. A further significant conclusion is that the assumption can be changed. Therefore this research concludes with the hope that through reflexive awareness of the social construction of the problem, the fatalistic attitude can be overcome and replaced with hope and vision to serve as the basis for a reconstruction and transformation of the metaphysical assumption and social institutions maintaining it.

Also, far from assuming a conspiracy by professionals, and to conclude with a judgement of the engineering profession and other social institutions, the research instead has proffered an understanding of how the processes are socially constructed to create an ideology that is largely unconsciously held and hence can be overcome. The conclusion of the research is rather that an emphasis on personal integrity to be responsibly involved in the construction of social activities is required. This process of responsibility and non-judgement is found to be linked with creativity, wisdom, the sacred and grace; and is found to be the needed focus of appropriate integrated management. It has formed the basis for viewing engineering and management as art as well as science in social, ecological and spiritual contexts.

From this recognition of the hopeful and creative potential, social construction of the required principles for better floodplain management has been undertaken through conversation with Regional Council staff and members of the public including Maori Iwi. The conversations have been about floodplain management in general and so the social construction has been about processes and methodology able to be implemented generally.

Three main guiding principles and four main practical conclusions have emerged from the reconstruction process.

## 11.1 MAIN PRINCIPLES

The first principle is that the metaphysic of objectivism and its correlate of rationalism is to be avoided as a basis for knowledge and legitimizing truth. At every turn a decision had to be made whether to opt for assuming an objective reality and rational discourse, or to remain in awe in face of intrinsic values and mysterious other possible worlds that could be constructed. Conceptually there was a choice between privileging a mechanistic metaphor expressed by the analysis and implementation of power to maintain the status quo, and an organismic metaphor of unfolding ontological and integrative growth (personal, human community and ecosystemic). This came to be found to be the fundamental decision and found to distinguish modernity from postmodernity. This research opted for awe in face of intrinsic values and a pragmatic non-metaphysical epistemology that holds functionality and use of an organismic metaphor as central. Such an approach has allowed the full exploration by creativity and engagement by the whole person so as to be aware of *wilderness* as the ethical and *civilizing* principle for social organization. It has been argued that it is what allows engineering to be an expression of art and to be holistic, while at the same time pragmatic and practical.

Another main principle that emerged is that social reconstruction is required to be fundamentally and deeply democratic and egalitarian; where all views, even those causing conflict, are inherently meaningful. When expressed within reconstructive postmodernism (the first principle) it is theoretically grounded and enables the concern for social justice and ethics generally to be implemented without nihilistic tendencies or naive relativism found in liberal traditions. Authority and responsibility to teach does not contradict others' freedom to their own sense of responsibility and creativity.

However the second principle brings a rub, which has been experienced personally by myself while embarked on this research. Elite views fitting atop metaphysics of objectivity and rationalism are very critical of the deprivileging of science and technology, and so in their analyses and implementation of power repress the attempt to question (deconstruct) and change (reconstruct) the status quo. Conflict is not embodied holistically as a source of information. However, reflexively, postmodern ethics expects this repression of critical feedback and the experience of it can be interpreted as necessary sacrifice that nurtures growth of others. When understood in this way it need not disturb the practitioner - it is meaningful. It has made this PhD research, for example, an inspiring time of personal growth.

The final main principle is that the sacrifice that is involved in de/reconstruction, if carried out with technical rigour, enables communication to be achieved and hence the

encouragement of meditation by technical elites that they may find can lead them to the abandonment of their elitism and fatalism and reconstruction of better alternatives. This has been attempted here through rigorous incorporation of imprecision and uncertainty into analyses. The result is that the mechanistic metaphor has been able to be proven to be less universally applicable than presumed. However the possibility of reconstruction adds to the final main principle the need for recognition that reactionary responses, which reject technology and individual rights that modernity has given so far, are inappropriate as the mechanistic metaphor does have a legitimate role. The challenge is to appreciate what it is. What is required, and has been attempted here, is the gaining of a deep enough appreciation of what modernity and technology are so as to allow the continual development of them both through nesting of their legitimate analyses within pragmatic and functional goal-seeking analyzed with an organismic metaphor, and nurtured in reflexivity by mythic metaphor.

## **11.2 PRACTICAL CONCLUSIONS**

The final principle gives rise to the practical conclusion that information technology, through incorporation of the analysis of imprecision and uncertainty, can actually enhance the values it has been correctly accused of eroding in the past. A methodology has been developed which uses an integrating algorithm which analyses within an Expert system (ES), with machine learning capability, in a way which can aid communication between publics (including technical expertise). It is through enhancing communication and resultant learning that a coherent integration has been achieved between technology manipulating so as to redistribute utility values; the liberal view of individual rights; spiritual vision, and appreciation of the meaning of conflict situations where very different worldviews are expressed.

Paradoxically, the research has brought deep recognition of the failures and fatalism at the core of Western (Pakeha) society and professional engineering institutions, but out of it also a vision and hope that can be practically operationalized to help lead to recovery through institutions nurturing wisdom.

The second practical conclusion is that the traditional Maori view can be integrated and is helpful. The traditional means of floodplain management carried out by Maori through the use of muru is sensible as it maintains the correct second-order feedbacks. However, ironically, the change in land tenure since Pakeha inhabitation of Aotearoa/New Zealand to individual ownership means that the expectation of individual responsibility, that the implementation of muru demands, is no longer appropriate. People are now far

more constrained as to where they live because of economic reasons. Ironically individual property rights means that responsibility has to be collective, and analysis of hazards has to be institutionalized. The systemic nature of the social construction of hazards and risk has to be recognized and to be operationalized.

To help in this another feature of Maori views is very helpful. It is the view of immortal gods which helps define the appropriate hierarchical systems levels where integration (and collectivity) is required so as to define the functions of engineered systems. This cultural heritage is consonant also with the spiritual heritage of the Pakeha.

Both need to be nurtured. Decision-making methodology to do so has been developed, according to systems levels defined thus, through development of information technology theory.

The third practical conclusion is that the integration requires specific definition of goals linked to processes associated with the functioning of the systems. This requires major changes to economic analysis and in particular the role ascribed to capital. Functionality means that profit cannot be seen as an end in itself. It is an inadequate guide as to what is a sustainable economic activity.

The fourth practical conclusion is that the three engineered systems at present making up floodplain management can be usefully developed so as to improve floodplain management through their functional integration at the defined systems levels. Specifically, the continued development of flood warning and concern with flood-proofing, and the continued development of contingency planning and zoning along with management of systemic services, are useful. The decision-making methodology can promote development of the specific systems and the integration of them.

All four practical conclusions support each other. The development of the various engineered systems can be achieved through use of ESs. The way to structure the algorithms of the ESs requires specific definition of goal-seeking systems, which involves personal integrity and collective responsibility nurtured by awareness of holistic principles through encouragement of cultural heritage.

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# Computer programmes

## A.1 PROGRAMME FOR THE SOLUTION OF A CUMULATIVE DISTRIBUTION

```

c      CDF.FOR
c      Program to numerically integrate the cumulative
c      distribution for a Poisson process with;- mean (theta)
c              - exponentially distributed value
c              for each event of mean (rho)
c
real tsum(0:2000)
real check(0:2000)
real ex(0:1000)
character*30 iofile
write(6,*) ' Enter the name of the input data file.'
read(5,'(a30)') iofile
open(20,file=iofile,status='old')
write(6,*) ' Enter the name of the output file'
read(5,'(a30)') iofile
open(10,file=iofile,status='new')
read(20,2000) theta,rho,ix,aint,aint2
write(10,3000)
kount=1
check(0)=0
do 100 m=0,(ix*aint)
    tsum(m)=exp(-theta)
    fact=1.0
    gamma=1.0
    do 101 k=1,theta*2
        sum1=0
        if(k.ne.1) then

```

```

        gamma=gamma*(k-1)
        if(gamma.gt.1.0e24) goto 109
    end if
    do 102 j=1,(m*aint2)
        aj=j
        if(k.ne.1) then
            sum=(1/rho)*(aj/(rho*aint*aint2))**(k-1)
        else
            sum=(1/rho)*(aj/(aint*aint2))
        end if
        if(sum.gt.1.0e24) goto 109
        sump1=sum*exp(-(1/rho)*aj/(aint*aint2))
        sump=sump1*(1.0/(aint*aint2))/gamma
        sum1=sum1+sump
102  continue
113      fact=fact*k
        asum=sum1*(theta**k)*exp(-theta)/fact
        tsum(m)=tsum(m)+asum
        if(asum.le.1.0e-6) go to 109
101  continue
109  am=m
        ex(m)=am/aint
        write(10,1000) ex(m), tsum(m)
c      check(kount)=tsum(m)
c      small=abs(tsum(m)-check(kount-1))
c      if(small.le.1.0e-2) then
c          if(kount.eq.20.and.tsum(m).gt.0.5) goto 110
c          kount=kount+1
c      else
c          kount=1
c      end if
c      amax=tsum(m)
100  continue
c 110  continue
c      kdm=m-kount

```

```

c      middle=int(theta*rho*aint)
c      kd=kdm/aint
c      mid=theta*rho
c      diff1=tsum(0)-exp(-theta)
c      diff2=tsum(middle)-0.5
c      diff3=tsum(kdm)-1.0
c      do 111 m1=0,(ix*aint)
c          x=m1/aint
c          adjust=tsum(m1)-p(x,diff1,diff2,diff3,mid,kd)
c      write(10,1000) ex(m1),adjust
c 111  continue
c      write(6,*) diff1,diff2,diff3
1000  format(1x,2f8.2)
2000  format(1x,2f6.2,i6,2f6.2)
3000  format(1x,'    x    ','P(X<x)',/)
      end
c
c
c      Function p(x,diff1,diff2,diff3,mid,kd)
c      Function to determine a quadratic interpolation.
c      p=diff1+(diff2-diff1)*x/mid
c      p=p+x*(x-mid)*(((diff3-diff2)/(kd-mid))-((diff2-diff1)/mid))/kd
c      END

```

## A.2 PROGRAMME FOR A MONTE-CARLO SIMULATION OF STREAMFLOW

```
character*30 iofile
integer isk(200),position(200),jtime(0:100),lag(50)
integer out(50),iflag(50),time(50),jik(50)
integer length(50,0:1000)
real dep(20),adpt(200),return(50)
write(6,*) ' Enter the name of the input file.'
read(5,'(a30)') iofile
open(1,file=iofile,status='old')
write(6,*) ' Enter the name of the output file.'
read(5,'(a30)') iofile
open(2,file=iofile,status='new')
c write(6,*) ' Enter the name of the print file.'
c read (5,'(a30)') iofile
c open(3,file=iofile,status='new')
c
c
c
read(1,1000) n,a,b,jzong,ilag,start,sink
call Expo(a,atime,itime,jtime)
i=0
number=0
itb=nint(a)
do 700 jz=1,20
position(jz)=0
iflag(jz)=0
lag(jz)=0
jik(jz)=0
time(jz)=0
700 continue
100 if(i.ge.n) goto 101
call Random(a,atime,itime,jtime,jzong,at)
it=nint(at)
call Depth(b,a,jzong,itb,adpt)
```

```

call Soak(itb,is)
itb=it
number=number+1
adpt(number)=adpt
isk(number)=is
do 400 k=1,itb
    ddepth=0.0
    jdk=i+k-1
    if(number.eq.0) then
        goto 401
    endif
    j=0
200   j=j+1
    if(j.eq.number+1) goto 201
    position(j)=position(j)+1
    sk=isk(j)
    dpt=adpt(j)
    osit=position(j)
    dep(j)=storm(sk,dpt,osit)
    if(position(j).ne.1.and.dep(j).le.0) then
        if(j.ne.number) then
            do 500 istep=j+1,number
                isk(istep-1)=isk(istep)
                position(istep-1)=position(istep)
                adpt(istep-1)=adpt(istep)
500   continue
            position(number)=0
            number=number-1
            j=j-1
            goto 200
        else
            if(number.eq.1) then
                position(1)=1
            endif
            number=number-1

```



```

                                goto 401
                                endif
                                else
                                ddepth=ddepth+dep(j)
                                endif
                                goto 200
201  continue
c 401  write(3,*) jdk,ddepth
401  do 800 kdm=1,15
                                slevel=start+sink*(kdm-1)
                                if(ddepth.ge.slevel) then
                                if(lag(kdm).gt.ilag) then
                                out(kdm)=out(kdm)+1
                                lag(kdm)=0
                                if(iflag(kdm).eq.0) then
                                length(kdm,jik(kdm))=time(kdm)+1
                                jik(kdm)=jik(kdm)+1
                                time(kdm)=0
                                iflag(kdm)=999
                                else
                                time(kdm)=time(kdm)+1
                                endif
                                else
                                iflag(kdm)=0
                                time(kdm)=time(kdm)+1
                                lag(kdm)=0
                                endif
                                else
                                lag(kdm)=lag(kdm)+1
                                time(kdm)=time(kdm)+1
                                iflag(kdm)=0
                                endif
800  continue
400  continue
                                i=i+it

```

```

        goto 100
101  continue
c    do 900 jdm=1,50
c        if(out(jdm).ne.0) then
c            return(jdm)=n/(365.25*out(jdm))
c        else
c            return(jdm)=0.0
c        endif
c        slevel=start+sink*jdm
c        write(2,*) return(jdm),slevel
c900  continue
        do 910 josh=0,1000
            write(2,3000) (length(limp,josh),limp=1,15)
910  continue
1000  format(1x,i10,2f6.2,i5,i2,2f4.0)
2000  format(1x,i10,f8.2)
3000  format(1x,15i5)
        END

```

```

c
c
        Function Storm(sk,dpt,osit)
c  Function to calculate flow in the hydrograph.
        pot=sqrt(0.25*sk**2+2*dpt)-0.5*sk
        if(osit.le.sk) then
            storm=osit*pot/sk
        else
            storm=pot-osit+sk
        endif
        END

```

```

c
c
        Subroutine Expo(a,aincr,number,itot)
        integer itot(0:100)
c
c  Determine the fit of a finite number of objects to

```

c an exponential distribution.

c

```
k=1000
```

```
min=0
```

```
ak=k
```

```
do 100 j=4,20
```

```
    aj=j
```

```
    aincr=a/aj
```

```
    kount=0
```

```
    number=0
```

```
    do 200 l=1,100
```

```
        kount=kount+nint(ak*(exp(-(l-1)/aj)-exp(-l/aj)))
```

```
        number=number+1
```

```
        if((exp(-l/aj)).le.(1.0/ak)) goto 10
```

```
200    continue
```

```
    10        if(abs(kount-k).le.min) goto 20
```

```
100    continue
```

```
    20        itot(0)=0
```

```
        do 300 n=1,number
```

```
            inc=nint(ak*(exp(-(n-1)/aj)-exp(-n/aj)))
```

```
            itot(n)=itot(n-1)+inc
```

```
300    continue
```

```
END
```

c

c

```
Subroutine Random(a,aincr,kim,itot,jzong,arand)
```

```
integer itot(0:100)
```

c

c Program to pick random numbers according to an

c exponential distribution.

c

c Select a random number from the distribution.

c

```
itot(0)=0
```

```
rand=ran(jzong)
```

```
iranzt=nint(rand*1000)
```

```
do 400 int=1,km
```

```
    if(iranzt.le.itot(int).and.iranzt.gt.itot(int-1)) then
```

```
        arand=aincr*(2*int-1)/2
```

```
    endif
```

```
400 continue
```

```
END
```

```
c
```

```
c
```

```
Subroutine Depth(a,b,jzong,ird,atd)
```

```
integer jdepth(0:100)
```

```
c
```

```
c Subroutine to pick a random number from an exponential
```

```
c distribution that has a dependent parameter.
```

```
c
```

```
    ajust=a
```

```
c
```

```
    ajust=a*2*ird/b
```

```
    call Expo(ajust,adepth,kdepth,jdepth)
```

```
    call Random(ajust,adepth,kdepth,jdepth,jzong,atd)
```

```
END
```

```
c
```

```
c
```

```
Subroutine Soak(it,is)
```

```
c
```

```
c Subroutine to determine the lag as a function of time since last
```

```
c storm.
```

```
c
```

```
    at=it
```

```
    if(it.ge.24) then
```

```
        is=4
```

```
    else
```

```
        is=nint(at/6)
```

```
    endif
```

```
END
```

# Questionnaire 1

## **B.1 PRIVATE CONSULTANTS IN FLOODPLAIN MANAGEMENT**

1. What is it that you are contracted to do?
2. Who are you contracted by?
3. What is the role of consultants in floodplain management?
4. What other groups are you engaged with in the work?
5. Are the relationships formal and/or informal?
6. What are the arrangements that you enter into?
7. Do you find informal agreements/obligations are holding?
8. To what extent do your professional and personal ethics become a factor in decision making.
9. Do you find the involvement with the community helps ethical principles to be implemented?
10. What are the ethical principles that you think underlie floodplain management?
11. Are the ethical principles universal?
12. To what extent is involvement with the community possible?
13. Is the degree of involvement with the community of the floodplain that is possible, a limitation to the maintaining of ethics?
14. How do you view the values of the community? Are they an irrational problem or the essential parameters?
15. What are the methodologies used?
  - to what extent are economic(C.B.A.) analyses used?
  - where do they come in priority?
  - how are social and environmental issues tackled (integrated)?
  - what priority do they have?
  - how do you determine priority?
  - how do you perceive willingness-to-pay analysis?

16. Do you find your ethical principles are in conflict with the methodology of floodplain management?
17. How do you view intuitive judgements about risk, and other concerns in floodplain management?
18. How do you view probabilistic interpretation?
19. How do you handle uncertainty and imprecision?
20. How is risk perceived?
  - is it part of a C.B.A. or a criterion in itself?
21. What view do you have of public participation?
  - to what extent is it an intrinsic good ( e.g. for the principle of democracy) and/or an extrinsic good (useful) for mandating decisions and conflict resolution?
22. To what extent and when do you use public participation?
23. Is it used formally and/or informally?
24. Do you actually take account of the public's perception of the problem?
25. What type of information/evaluation is required for court use?
26. What effect has computer software had?
27. Has it narrowed the scope of analysis/appreciation of values?
28. Has it affected the extent of informal communication?
29. Has it affected the use of intuitive judgement?
30. Has it led to 'better' solutions: more just, sensible, rational?
31. What is a better solution?

Questions 32-35 refer to diagram 1.

32. Are there other issues not mentioned here?
33. Are the relationships expressed correctly?
34. What are the priorities used?
35. How are the priorities determined?

## **B.2 FLOODPLAIN MANAGERS**

The first two questions refer to diagram 1.

A formal relationship is defined here as one given by legal and commercial arrangements.

An informal relationship is defined as one which isn't formal, e.g. personal communication with resident associations.

1. Do you have informal relationships with the other groups in the diagram?
2. Are there other groups that are also part of the system in the diagram, and do you have informal relationships with them?
3. What informal groups exist to encourage informal organization?
4. What professional groups exist to encourage it?
5. How successful are they?
6. Are there formal structures (including professional organizations and other social groups) that interfere with informal contacts and organization?
7. What areas of concern are able to be helped by informal contacts and organization?
8. What areas require formal structures?
9. Do you change from informal to formal arrangements if there is lack of cooperation?
10. Do you ever change from formal to informal arrangements?
11. What type of contact do you initiate involvement with?
12. Is there a perceived need to formalize existing successful informal arrangements?
13. What are your formal relationships with other organizations?
14. How has regional government reform affected the informal organization?
15. How is R.M.L.R. expected to affect informal organization, and formal activities?
16. Do you see increased market and court use affecting formal and informal arrangements? If so how?
17. What type of information/evaluation is required for court use?
18. To what extent do your professional and personal ethics become a factor in decision making.
19. Do you find the involvement with the community helps ethical principles to be implemented?
20. How do you view the values of the community? Are they an irrational problem or the essential parameters?

21. What are the ethical principles that you think underlie floodplain management?
22. Are the ethical principles universal?
23. Do you use consultants for any planning activities?
24. How do they fit into the informal organization?
25. What areas do you use consultants for?
26. What are the methodologies used?
  - to what extent are economic(C.B.A.) analyses used?
  - where do they come in priority?
  - how are social and environmental issues tackled (integrated)?
  - what priority do they have?
  - how do you determine priority?
  - how do you perceive willingness-to-pay analysis?
27. Do you find your (or any other) ethical views are in conflict with the methodology of floodplain management?
27. How do you view intuitive judgements about risk, and other concerns in floodplain management?
28. How do you view probabilistic interpretation?
29. How do you handle uncertainty and imprecision?
30. How is risk perceived?
  - is it part of a C.B.A. or a criterion in itself?
31. What view do you have of public participation?
  - to what extent is it an intrinsic good ( e.g. for the principle of democracy) and/or an extrinsic good (useful) for mandating decisions and conflict resolution?
32. To what extent and when do you use public participation?
33. Is it used formally and/or informally?
34. Do you actually take account of the public's perception of the problem?
34. What procedures are used for conflict resolution between groups?
35. Do you automatically invoke formal (legal and market) forces, or do you endeavour to



resolve conflicts informally first?

36. If you try to resolve them formally first do you see public participation as having a place in this? Do you use this?

37. Do you find informal agreements/obligations are holding?

38. What effect has computer software had?

39. Has it narrowed the scope of analysis/appreciation of values?

40. Has it affected the extent of informal communication?

41. Has it affected the use of intuitive judgement?

42. Has it led to 'better' solutions: more just, sensible, rational?

43. What is a better solution?

44. What effect do insurance companies have on the decisions made?

45. Are they increasing the uncertainty/risk?

46. What effect does/did central government aid and subsidies have on the decisions made?

47. What effect do land valuers and land agents have on the decisions made?

Questions 47-50 refer to diagram 2.

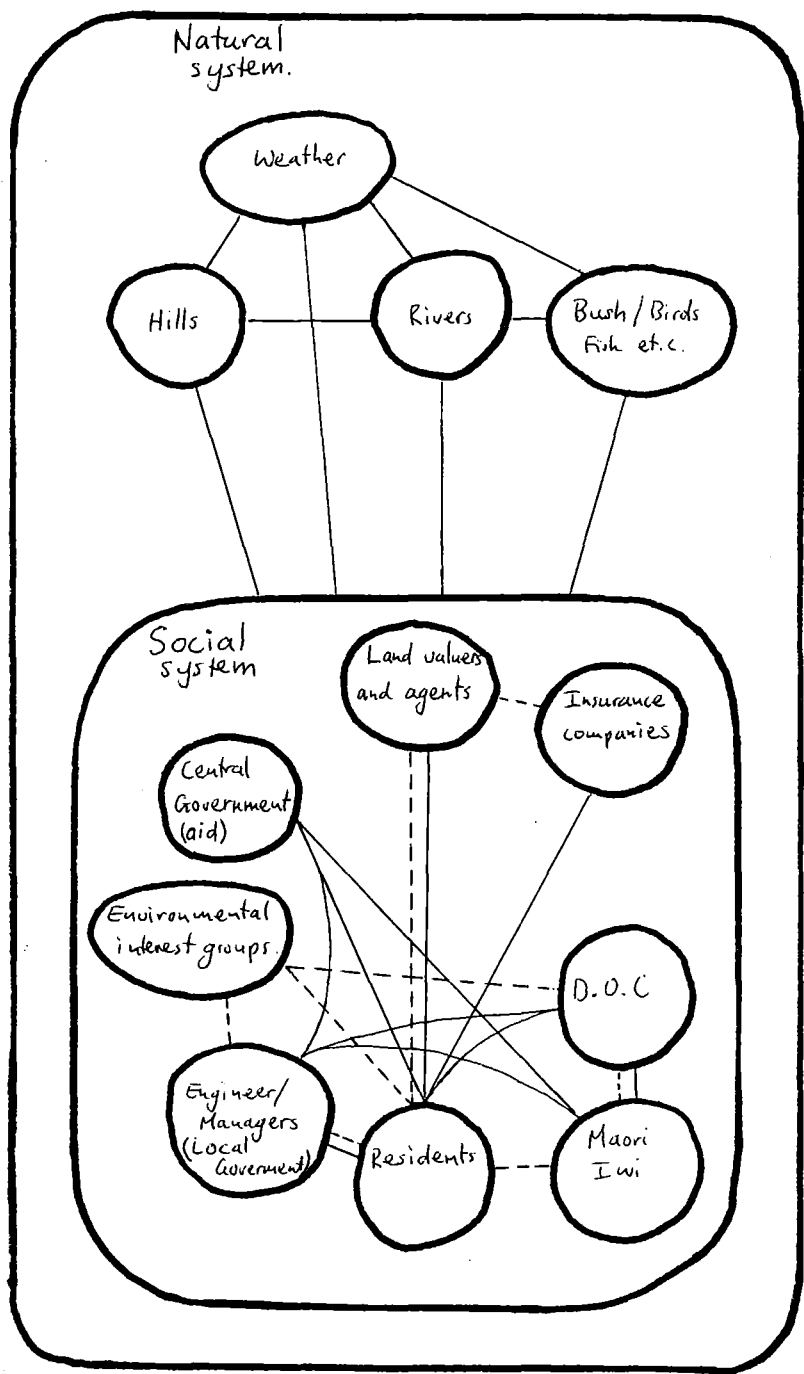
48. Are there other issues not mentioned here?

49. Are the relationships expressed correctly?

50. What are the priorities used?

51. How are the priorities determined?

Diagram 1.



In the social system:  
—— formal arrangement.  
----- informal arrangement.

Figure B.1; Floodplain system.

Diagram 2.

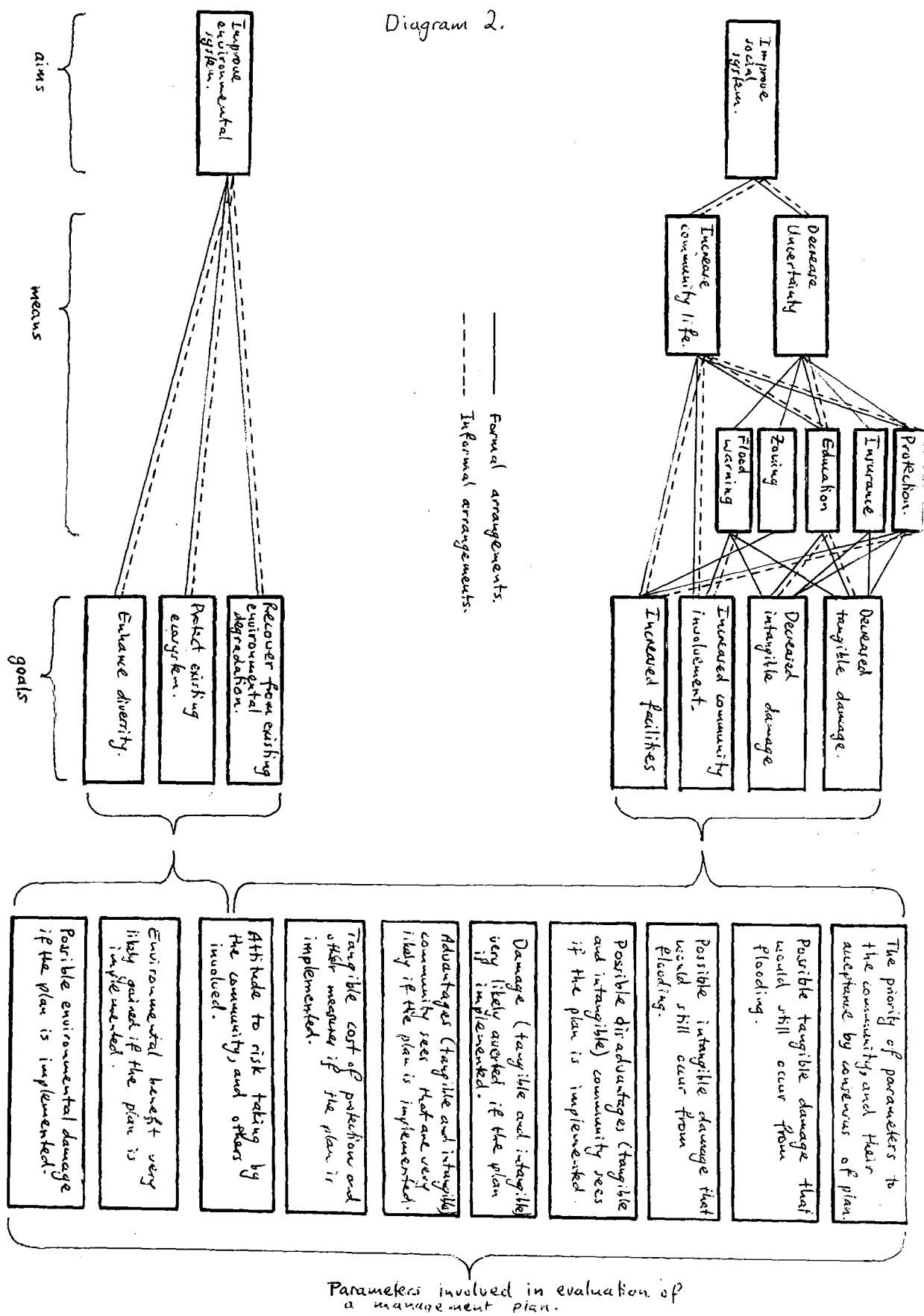


Figure B.2; Floodplain management parameters.

## Questionnaire 2

### **C.1 SUGGESTED APPROACH TO FLOODPLAIN MANAGEMENT**

The aim has been to produce a thoroughly pro-active approach which allows fulfilment of the spirit and letter of the Resource Management Act.

There are three criteria used for the development of an adequate and appropriate floodplain management plan as part of a regional plan. The three criteria are: ethics, realism, and practicality. The three criteria are interwoven.

The ethics criterion is represented in the ideal or vision being aimed for. This is defined as sustainable community development. Therefore this means the harmonious life within bio-regions, or specific floodplain ecosystems, respecting the intrinsic values of all the species involved and fulfilling the needs of the human community. The process of community development to respect the intrinsic values of the people involved needs to occur in the process of participatory democracy.

The realism criterion is represented in concern for awareness of the constraints in the process of development. There are two aspects to the constraints: limits to power over natural forces, and an ethical aspect referring of the limits of acceptable power. The two aspects are interwoven. Limits to power occur in the physical constraints in inability to totally control natural forces hence resulting in unavoidable natural hazards. Limits to power also occur in limits in the amount of social change which is due to political factors. Ethical aspects occur in the willingness to respect intrinsic values and hence seek ecological sustainability before resources depletion becomes a limit to power to control, and in the willingness to respect participatory democracy as the means of social change which is sustainable and where the needs of all the groups in the floodplain community are respected.

The practicality criterion is represented in the seeking of evolutionary steps which improve the situation. These head toward the ethical ideal and need to be realistic. A set of procedures forming a methodology to allow the determination of practical steps of improvement has been developed. The features of this methodology are given below. It is a 'soft systems methodology' incorporating a 'guidance expert system'.

## **Overview of Procedures.**

1. Determine who are the stakeholders in the floodplain. This includes non-human interests. Essentially it is all which have intrinsic values associated.
2. Through dialogue with stakeholders (this can be their representatives, or advocates in the case of non-humans) determine what their worldviews are: incorporating; visions (ideals), goals, and claimed needs.
3. Determine through the use of available technical means, including through the use of consultants, the physical, ecological and political information relating to what can be controlled and what the constraints are.
4. Attempt to synthesize plausible floodplain management plans from the set of worldview features obtained in 2 in light of 3. This process involves the use of a 'guidance expert system'.

## **Guidance Expert System.**

There are three components: Advisor, Structure graph, and Workpad. See figure 1.

### **1. Advisor.**

This involves a scoping process to determine whether or not and where contradictions in fulfilling of needs occur. Three categories of situations are clarified. They are:

- (i) Political issues where trust and cooperation are not available.
- (ii) Situations available to effective solution through the interdisciplinary use of consultants interacting with dialogue and cooperation with the groups of stakeholders to produce smooth operating of the functional aspects of society and the wider ecosystem.
- (iii) Situations requiring only technical solutions to clearly defined problems, which fulfil functional requirements.

With this information, suggestions as to where the root causes of contradictions are can be given. This is effectively clarifying the social constraints present and how to transform the situation ethically. Awareness of the changing physical and ecological constraints also needs to be carried out here.

### **2. Structure Graph.**

An initial suggested structure for consideration of plausible options is suggested here. It is open to review by the 'Advisor'. There is a hierarchy of three levels:

2 - purpose

1 - goals

0 - means

Level 2 can be described as a vision and is what is considered in the ethical criterion. It is a vision of community development where all the intrinsic values present in the floodplain are nurtured.

Level 1 has three aspects to it. They all refer to needs necessarily determined from within public participation forums.

(i) Structural or functional aspects which provide the services for society. This includes ethical concerns for equity. Such structures needing to be considered include;

- water supply network.
- electricity supply network.
- sewage network.
- telephone network.
- transport network.
- information transmission and participation forums.
- insurance system.
- flood warning systems.
- emergency systems.
- zoning plans.
- economic development plans.
- physical structural protection.

Secondly, functional components necessary for the sustaining of the floodplain ecosystem or natural heritage. These are determined by ecological principles. They can be considered to be a subset or extension of the zoning criterion above. They include the need for:

- wetlands
- river flats.
- wooded catchments (preferably with indigenous forest).

Thirdly, the cultural aspects that can be described as a 'sense of place' which fulfil necessary elements for community relationships. This refers to respecting the integrity of lifestyles or cultural heritage. This includes specific Maori requirements in respect of the Treaty of Waitangi, e.g.:

- wahi tapu.
- mahinga kai.

- not 'mixing the waters' of hydrological systems.

It also includes respecting:

- recreational sites.
- landscapes and views.

Level 0 refers to the resources required to fulfil the functional requirements of level 1.

These include:

- water
- electricity
- food
- information (zoning, hazards, flood proofing)
- money; production, tax, subsidies and relief.

Much of the information pertaining to the definition of facts about the features in level 0 and 1 can be held in a GIS. The use of GIS graphics helps this information gathering and communication to interface with the publics, and to allow for understanding to develop between the publics groups. This necessarily requires information about imprecision and uncertainty as the needs are not able to be precisely defined. Also logical relationships exist between them. These need to be defined as rules. Incorporating imprecision and uncertainty into rules results in fuzzy logic statements.

### **3. Workpad.**

The User uses a fuzzy logic algorithm to scan which sets of needs are plausible. With the Advisor module difficult areas are isolated and provide information as to what needs to be discussed in further public discussions, to try to build up trust and cooperation between the various groups of stakeholders. To the extent that this is achieved the legal requirements in the RMA can be fulfilled yet avoid expensive adversarial interaction and hence unavoidable discrimination against certain interest groups.

### **Fuzzy Logic Algorithm.**

The relationships (rules) between the different needs require specialised formation requiring inter-disciplinary consultancy. Specifically: sociologists, ecologists, landscape architects and Maori consultants. If the rules are expressed as qualified statements and inferences then they can be put into the format of fuzzy logic.

Subjectively defined evaluations can be determined through techniques of sketching vague representations of evaluations and incorporated into GIS graphics. Objective

information with its imprecision and uncertainty can also be incorporated.

The rules can then be synthesized according to some decision hierarchy. As long as each goal and means can be related to another such a synthesis can always be made. The general configuration is given by Figure 2. The actual structure is determined by the relationships between the goals and means. The relationships will always have to be defined specifically but there are some general patterns which help direct determination of the relationships. See Figure 3 for a schematic outline of a suggested set of relationships.

The algorithm is changed through interaction with the Advisor. A schematic representation of the guidance expert system incorporating the algorithm is given in Figure 4.



# Guidance Expert System.

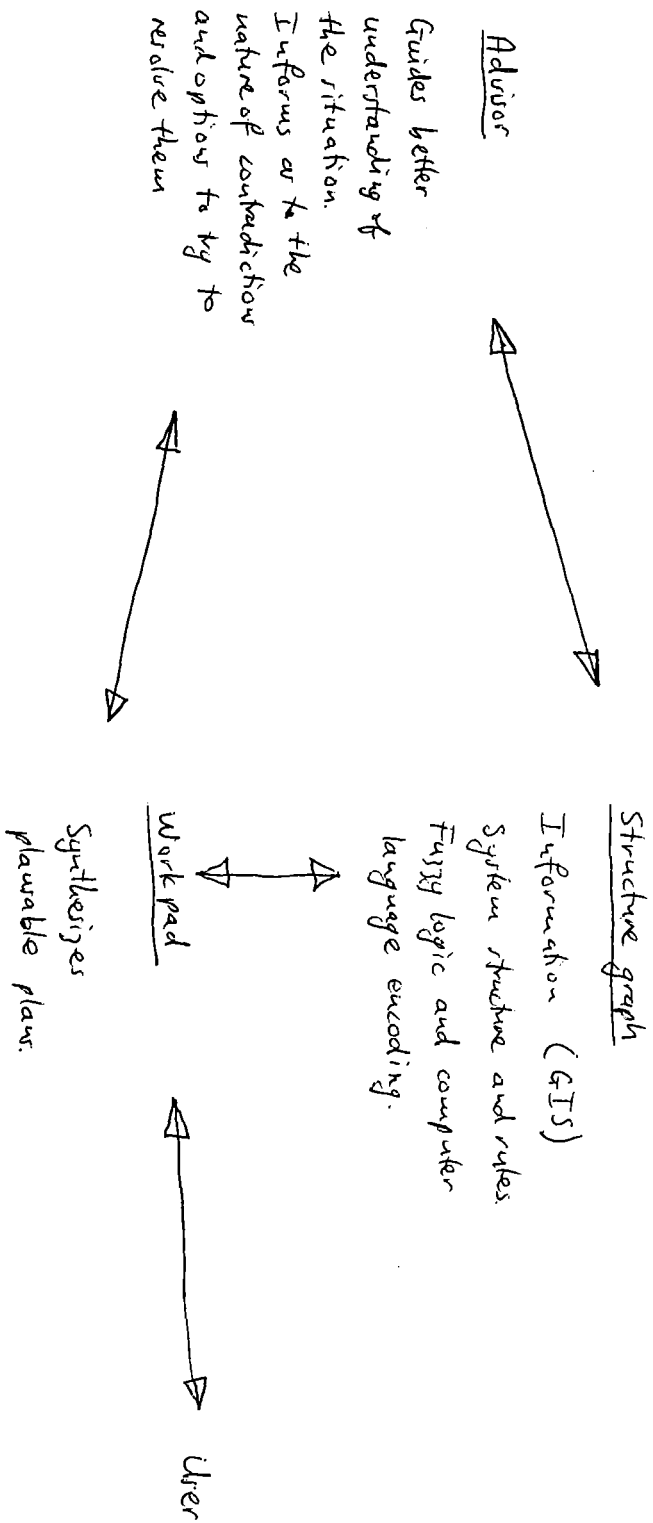
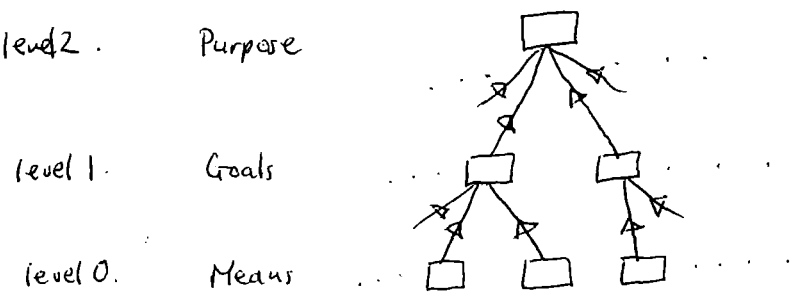


Figure 1.

Figure C.1; Guidance expert system.

System Hierarchy.



There can be feedbacks  
between level 0 and 1 .

figure 2.

Figure C.2; System hierarchy.

# Relationships between Needs.

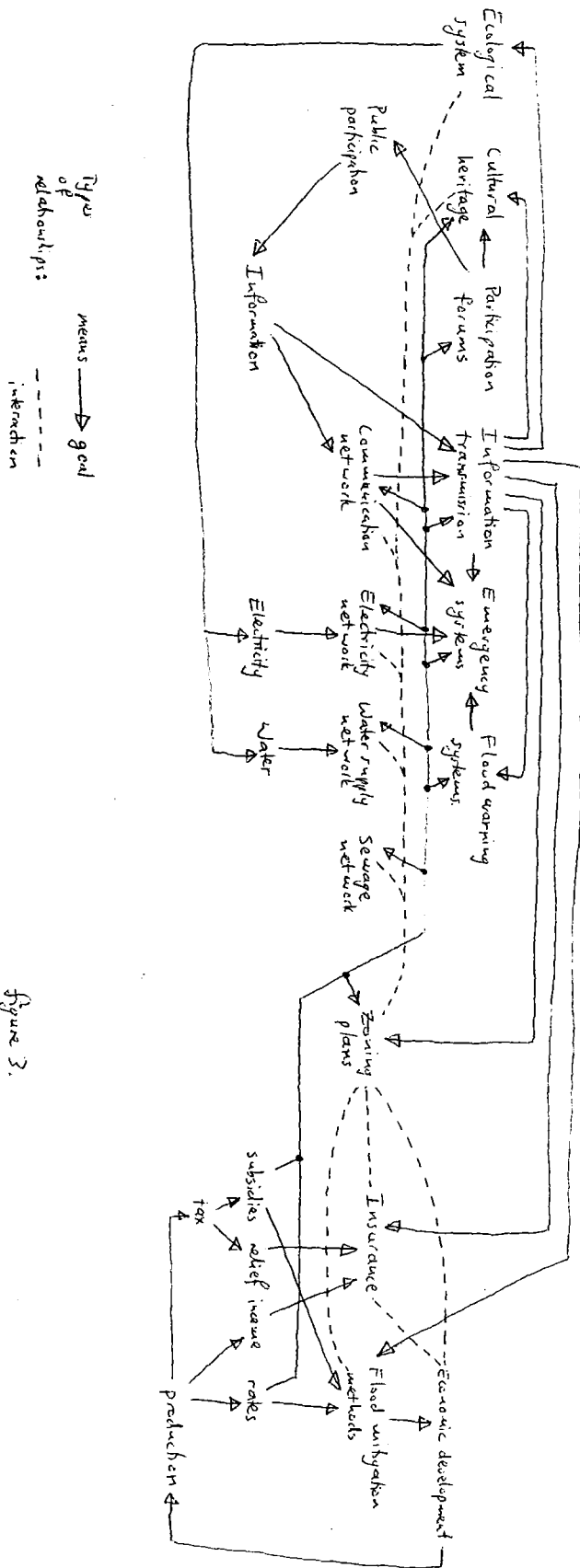


figure 3.

Figure C.3; Relationships between needs.

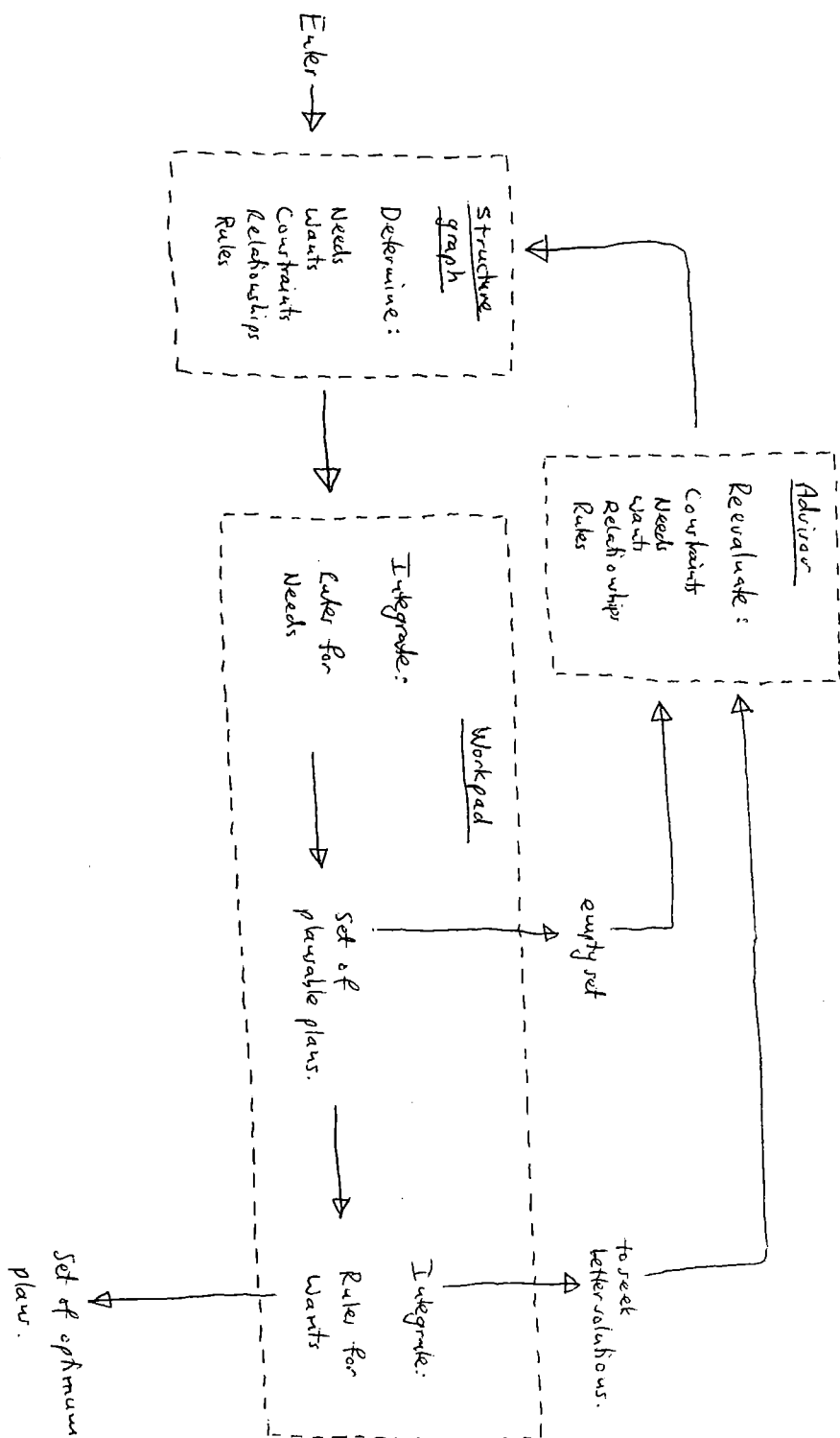


Figure 4.

Figure C.4; Floodplain management process.